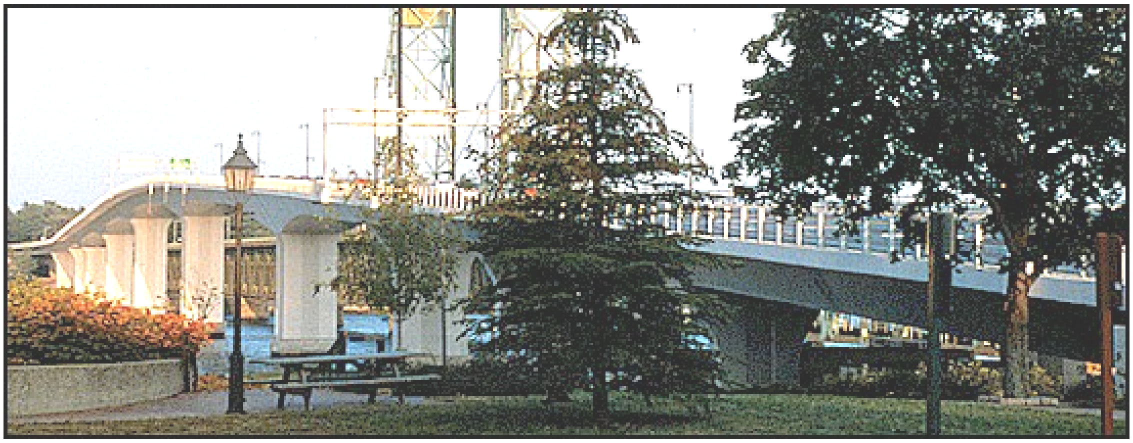
Chapter 4

SUPERSTRUCTURES



Sagadahoc Bridge, Bath-Woolwich

Kittery Point Bridge, Kittery

4 SUPERSTRUCTURES

4.1 Bridge Widths

4.1.1 General

Section 4.1 is a guide to determine the appropriate width of a bridge. For geometric design criteria for the width of the approaches to the bridge, refer to Section 2.8.1 Roadway Widths. For pedestrian and bicycle considerations, refer to Section 4.3 Curbs and Sidewalks and Section 4.4.4 Bicycle Railing.

As discussed in Section 2.8.1 Roadway Widths, all roads are classified according to function and further divided into two categories, urban and rural. For rural roads, bridge widths are given in Table 4-1 through Table 4-4. Bridges to Remain in Place are defined as those in which the substructure will remain in place without widening. Special Purpose Roads are a special type of local road that is defined further in Section 4.1.3.1C.

4.1.2 Urban Bridge Widths

For urban streets, the clear width for new bridges should be the same as the width of approaches. For bridges greater than 200 feet long on streets that have shoulders wider than 4 feet, the shoulders may be reduced to 4 feet on each side.

4.1.3 Rural Bridge Width Standards Tables

Table 4-1 through Table 4-4 are used as starting points for selecting bridge widths. Route continuity should be considered when determining widths for each project. Established or proposed corridor widths should be obtained from the Bureau of Planning. For bridges on local roads, proactive communication with municipal officials and/or planning boards will identify established or reasonable proposed corridor widths.

In addition to AADT and corridor width, other factors should be investigated before a final bridge width is determined. They include, but are not limited to, geometry, accident history, right-of-way and environmental impacts, archeological and historic concerns, local impacts, bicycle and pedestrian use, and cost.

Bridge widths are curb-to-curb or rail-to-rail, whichever is less. Exceptions to the bridge width standards must be obtained from the Engineer of Design. Exceptions to the bridge width standards on NHS roadways must also be obtained from FHWA.

4.1.3.1 New or Reconstructed Bridges

A. NHS

Table 4-1 Bridge Roadway Width Standards – Rural NHS

New or Reconstructed Bridges

Design Traffic AADT	Design Speed (mph)	Traveled Way (ft)	Bridge Width [1] (ft)
< 400	40-55	22 [2]	30
< 400	60-75	24 [3]	32
400-1500	40-55	22 [2]	34
400-1500	60-75	24 [3]	36
1500-2000	40-45	22 [2]	34
1500-2000	50-75	24 [3]	36
> 2000	40-75	24 [3]	40

1. Bridges greater than 200 feet long may have a reduced bridge width equal to the traveled way plus 4 foot shoulders on each side.

2. The traveled way pavement thickness should be paved full depth for a full 24 foot width.

3. Traveled way widths of 22 feet may be used if alignment and safety records are deemed satisfactory, and the existing corridor has a 22 foot traveled way width.

B. Non-NHS

Table 4-2 Bridge Roadway Width Standards – Rural Non-NHS

New or Reconstructed Bridges

Local Roads and Minor Collectors [1]

Design Traffic AADT	Design Speed (mph)	Traveled Way (ft)	Bridge Width (ft)
< 1000	40 [3]	22 [3,4]	28 [4]
1000-4000	40 [3]	22 [5]	30 [4,9]
> 4000	Refer to Major Collectors		

Major Collectors [1]

Design Traffic AADT	Design Speed (mph)	Traveled Way (ft)	Bridge Width (ft)
< 1000	45	22 [5]	28
1000-4000	45	22 [6]	30 [4,6,9]
4000-6000	45	22	34
6000-8000	45	24 [7]	36 [7]
> 8000	55	24 [8]	40 [8]

Minor Arterials [2]

Design Traffic AADT	Design Speed (mph)	Traveled Way (ft)	Bridge Width (ft)
< 1000	45	22 [5]	28
1000-4000	45	22 [6]	30 [4,6,9]
4000-6000	45	22	34
6000-8000	55	24 [7]	36 [7]
> 8000	55	24	40

1. Bridges located on local roads and all collectors greater than 100 feet long may have a reduced bridge width equal to the traveled way plus 4 foot shoulders on each side.

2. Bridges located on minor arterials greater than 200 feet long may have a reduced bridge width equal to the traveled way plus 4 foot shoulders on each side.

3. The Designer should scrutinize the design speeds for bridges on local roads on each project for the best fit in the local area.

4. In order to minimize impacts and costs and stay within the footprint of the existing highway, bridges on local roads that

have low speeds, good geometric characteristics, and low CRF may be considered for a decreased bridge width. When AADT<250, 22 foot bridge widths may be considered. When AADT is between 250 and 750, 24 foot bridge widths may be considered. When AADT <2000, 26 foot bridge widths may be considered.

5. When AADT is less than 1000, the traveled way width may be reduced to 20 feet, with bridge widths remaining 28 feet.

6. When AADT is 1000-4000, the traveled way width may be reduced to 20 feet, with bridge widths reduced to 28 feet.

7. When AADT is 6000-8000, the traveled way width may be reduced to 22 feet, with bridge widths reduced to 34 feet.

8. When AADT is greater than 8000, the traveled way width may be reduced to 22 feet, with bridge widths reduced to 30 feet.

9. When the bridge rail and approach guard rail lengths are continuous for greater than 1000 feet on each side, and AADT is between 2000-4000, consideration should be given to widening the rail to rail width to 32 feet to minimize conflict for snowplowing operations.

C. Special Purpose Roads

Special purpose roads are generally lightly traveled and of low speed, deserving special design consideration. They include recreational roads, resource development roads, and local service roads. Resource development roads include mining and logging roads, and the criteria for recreational roads should be followed where applicable. Local service roads serve isolated areas that have little or no potential for further development. Most of these roads will dead-end at the service to the last parcel of land. Traffic is generally less than 100 AADT and is of a repeat type. The criteria for recreational roads should be followed where applicable.

Table 4-3 Bridge Roadway Width Standards – Special Purpose Roads

New or Reconstructed Bridges

Type	Traveled Way [1] (ft)	Bridge Width (ft)
Primary Access Road (2-lane) [2]	22-24	26-32
Circulation Road (2-lane) [3]	20-22	24-30
Area Road (2-lane) [4]	18-20	18-24
Area Road (1-lane) [4,5]	12	12-14

1. Widening on the inside of sharp curves should be provided. This additional width should be equal to 400 divided by the curve radius in feet.

2. Primary access roads are roads that allow through movement into and between access areas.

3. Circulation roads are roads that allow movement between activity sites within an access area.

4. Area roads are roads that allow direct access to individual activity areas such as campgrounds, park areas, boat launching ramps, picnic groves, scenic sites, and historic sites.

5. Area roads with AADT<100 may be designed as a two-way, single lane roadway. Roadway widths greater than 14 feet should not be used because drivers will tend to use the facility as a two-lane road.

4.1.3.2 Bridges to Remain in Place

A. Arterials (NHS and Non-NHS)

For an existing bridge to remain in place on an arterial, it should have adequate structural strength and a bridge width equal to the approach traveled way width plus 2 feet on each side. Bridges on arterials should be considered for ultimate widening or replacement if they do not provide at least HL-93 loadings. As an interim measure, narrow bridges should be considered for special narrow bridge treatments such as signing and pavement marking.

B. Collectors and Local

Table 4-4 Bridges to Remain in Place – Rural Non-NHS

Minimum Bridge Widths

Design Traffic AADT	Local [1,2,3] (ft)	Collector [3] (ft)
< 250	20	22
250-1500	22	22
1500-2000	24	24
> 2000	28	28

1. On local roads with few trucks, widths may be reduced by 2 feet. In no case shall the minimum clear width be less than the approach traveled way width.

2. Bridges on local roads with AADT<50 may be considered for one lane. The preferred width is equal to the traveled way width plus 1 foot shoulders on each side, with a minimum bridge width of 14 feet and maximum bridge width of 18 feet.

3. The values do not apply to bridges greater than 100 feet in total length. These bridges should be analyzed individually, taking into consideration the clear width provided, traffic volume, remaining life of the structure, pedestrian volume, snow storage, design speed, accident record, and other pertinent factors.

4.2 Lighting

MaineDOT, via the project team, will recommend to a municipality that a bridge should be lighted when it would be in the best interests of the public. The policy for the overhead lighting of bridges is as follows:

- *Controlled Access Highways*. Bridges will be lighted when they are part of an interchange, where continuous lighting exists, and/or a need for lighting is established during preliminary design.

- *Non-Compact Areas*. A bridge in a non-compact area will only be considered for lighting when requested by the municipality and a need for lighting is established during preliminary design.

- *Compact Areas*. A bridge in a compact area should be lighted when at least one of the following is true:

    1. Lighting is requested by the municipality.

    2. Both approaches are lighted.

    3. There is significant pedestrian movement.

    4. Other safety issues are identified.

The cost of the installation of the light standards, foundations, and conduits are borne by MaineDOT on all bridges. The installation and maintenance of the wiring and the luminaries, as well as the cost of electricity, are the responsibility of the municipality, except on controlled access highways where MaineDOT is responsible.

MaineDOT's Traffic Engineering will determine the need and design for lighting under grade separation structures. The location of fixtures and level of illumination should be coordinated with Traffic Engineering, in accordance with "An Informational Guide for Roadway Lighting" (1984).

The Bridge Program is responsible for executing this lighting policy. Lighting needs should be documented in the PDR. Municipalities should be contacted as appropriate, and the City/State Agreement should appropriately reflect the arrangement.

4.3 Curbs and Sidewalks

For standard steel bridge railing, bridge curb reveal is generally 9 inches. Refer to Standard Detail 502 (03) for further guidance. On relatively short urban bridges, a reduced curb reveal can be considered to match approach curbs. Traffic railings should be flush with the face of curb except when calling for granite bridge curbing, where the face of curb will project 5 inches in front of the face of rail.

The need for sidewalks should be considered on a project-by-project basis. The only time sidewalks should be included on a bridge is when there are sidewalks on the approaches, or when the municipality has sidewalks at that location in its comprehensive plan. When a municipality requests that a sidewalk be placed on a bridge that does not require one, the municipality is expected to pay for the added cost of providing it.

Sidewalks with minimal pedestrian traffic should be 5 feet clear to the face of rail. Sidewalks with significant pedestrian traffic should be 6 feet clear to the face of rail. Sidewalk widths for very high pedestrian traffic should be determined on a project-by-project basis. Traffic railings or barriers separating vehicular traffic from pedestrian traffic should be considered only for exceptional cases. Sidewalks with no separation between pedestrian and vehicular traffic will require a combination pedestrian/traffic rail.

Wide sidewalks may hinder bridge inspection activities which use the under bridge crane. Bridge Maintenance should be consulted before proposing a sidewalk width greater than 6 feet.

Granite bridge curbing may be used only where granite curbing is called for on both approaches. In all other cases, curbs and sidewalks should be entirely concrete with a 1 inch batter of the face of the curb.

Concrete for curbs and sidewalks is Class LP.

4.4 Bridge Rail

4.4.1 Definitions

The following definitions are used when selecting a rail system.

- *Adjusted ADT:* ADT_{cy} adjusted for site condition criteria
- *ADT_{cy}:* average daily traffic for construction year
- *K_c:* adjustment factor for horizontal curvature of alignment (refer to Figure 4-2)
- *K_g:* adjustment factor for grade (refer to Figure 4-2)
- *K_s:* adjustment factor for deck height and under structure condtions (refer to Figure 4-3)

- *TL-1:* a test level 1 bridge rail generally acceptable for very low volume, low speed streets.
- *TL-2:* a test level 2 bridge rail generally acceptable for most local and collector roads with favorable site conditions.
- *TL-3:* a test level 3 bridge rail generally acceptable for a wide range of high speed arterial highways with very low mixtures of heavy vehicles and with favorable site conditions.
- *TL-4:* a test level 4 bridge rail generally acceptable for the majority of applications on high-speed highways with a mixture of trucks and heavy vehicles.
- *TL-5a:* a test level 5a bridge rail generally acceptable for the same applications as the TL-4, but when site conditions justify a higher level of rail resistance.
- *TL-5 & TL-6:* test level 5 & 6 bridge rails generally acceptable on high speed, high volume highways with a higher ratio of heavy vehicles and unfavorable site conditions.

4.4.2 General

AASHTO LRFD Section 13 states that new bridge railings and the attachment to the deck overhang must satisfy crash-testing requirements to demonstrate compliance with structural and geometric requirements of a specified railing test level. These test levels are TL-1 through TL-6. The previous railing performance categories recognized by AASHTO were the PL-1 to PL-3 levels. Most bridges in Maine will require a TL-4 rail or less. Table 4-5 gives the accepted equivalency of the previously used crash-test parameters:

Table 4-5 Bridge Rail Test Equivalencies

Bridge Railing Testing Criteria	Accepted Equivalencies						
AASHTO LRFD	TL-1	TL-2	TL-3	TL-4	TL-5a	TL-5	TL-6
AASHTO Guide Specification		PL-1		PL-2		PL-3	
NCHRP Report 350	TL-1	TL-2	TL-3	TL-4		TL-5	TL-6
NCHRP Report 230		MSL-1 MSL-2*		MSL-3			

* MSL-2 is close to a TL-3 but adequate TL-3 performance cannot be assured without a pickup truck test.

To determine the TL level rail required, refer to Section 4.4.3 Bridge Rail Selection. To determine if a pedestrian or bicycle rail is required, refer to Sections 4.3 Curbs and Sidewalks and 4.4.4 Bicycle Railing.

The choice of which rail to use will generally be made from the following list, although other crash-tested rails are available through the FHWA website http://safety.fhwa.dot.gov/fourthlevel/hardware/bridgerailings.htm. Use of a rail from another state requires approval from the Engineer of Design, since additional design and detailing time will be necessary.

Commentary: In the late 1970's and early 1980's crash tests were conducted on several commonly used railings that had been designed according to the static load standards of the day. These tests resulted in the failure of several of the railings. At that time, FHWA determined that static loadings were insufficient to determine adequate railing performance and bridge railings were then required to be crash-tested to NCHRP 230 standards. AASHTO published its "Guide Specifications for Bridge Railings" in the late 80's, which began the use of performance level selection for given site conditions. In 1993, NCHRP 350 was published which included six different "Test Levels" for testing rails. Currently, the FHWA requires that all bridge railings installed on NHS projects meet the criteria of NCHRP 350 Test Level - 3 (TL-3).

4.4.2.1 TL-2 Rails

These rails have been tested to TL-2:

- Texas Classic Rail
- Fascia Mounted Thrie Beam
- TL-2 Timber Rail systems (refer to Figure 4-1 for examples)
- Any of the TL-4 or TL-5 options

4.4.2.2 TL-4 Rails

These rails have been tested to TL-4:

- Galvanized Steel Bridge Rail
- TL-4 Timber Rail system
- Maine Modified Kansas Rail
- F-Shaped Barrier (Type IIIA)

F-shaped barrier should be used if a TL-4 rail is required and the length of bridge rail is less than 35 feet. When the design length of bridge rail is 20 feet or less, the approach guardrail may be carried over the structure using a 3’-1 1/2“ post spacing with a double layer of guardrail beam on the bridge structure and 50 feet beyond either end of the structure.

4.4.2.3 TL-5 Rails

This rail has been tested to TL-5: F-Shaped Barrier (Type IIIB)

4.4.3 Bridge Rail Selection

The criteria in this subsection are meant for the selection of an appropriate bridge rail system for new construction projects only. For rehabilitation projects, refer to Section 10.5 Bridge Rail and Connections.

Regardless of the Adjusted ADT, the Structural Designer is expected to use good engineering judgment in the selection of a railing system. For example, it may be desirable to have a rigid railing system in an area where there is a retaining wall located immediately behind the guardrail, even if there is no bridge on the project.

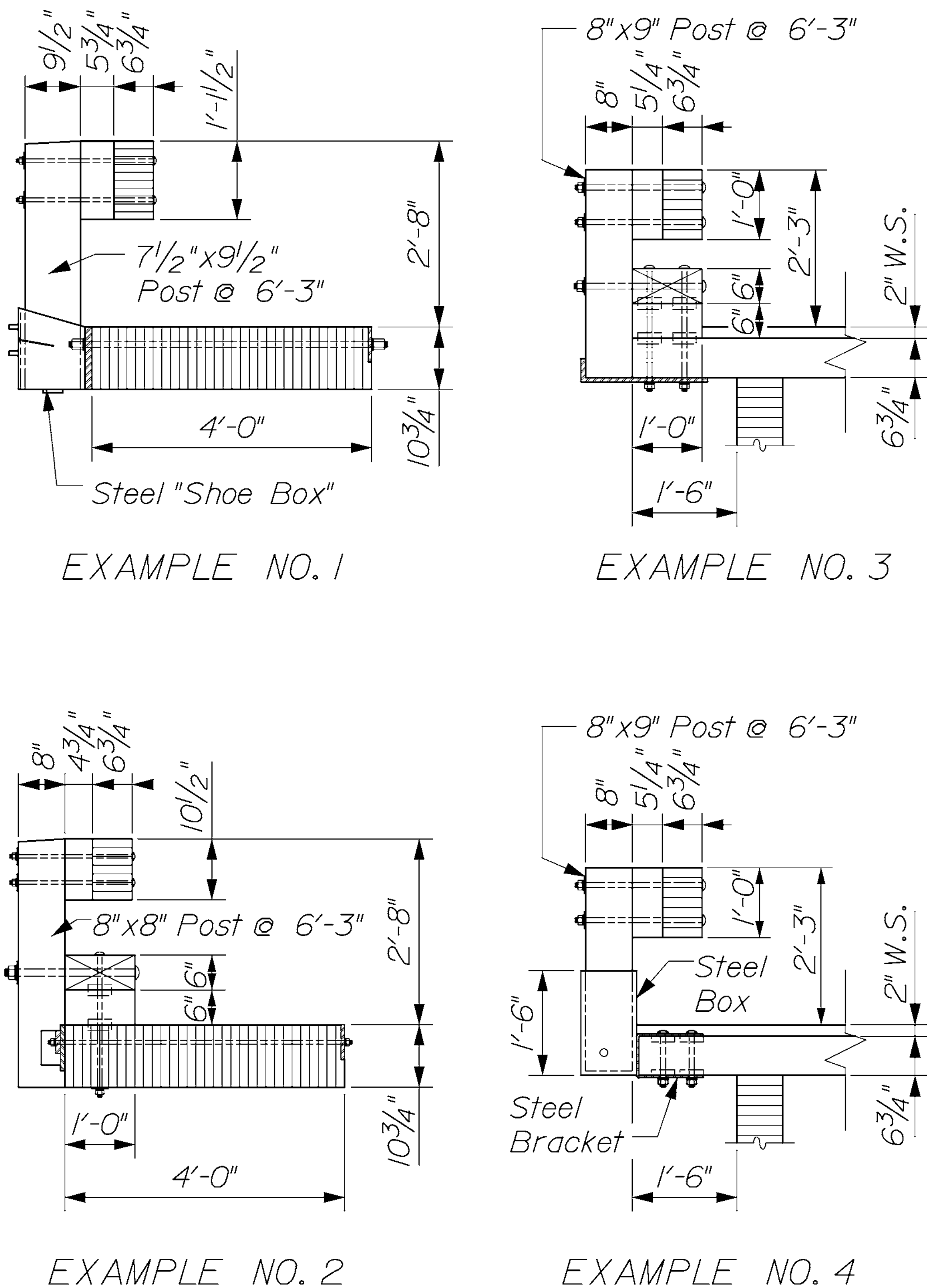


Figure 4-1 TL-2 Timber Rail Systems

Procedure 4-1 Rail Design

Step 1: Refer to Figure 4-2 and Figure 4-3 to determine K_c, K_g, & K_s.

Step 2: Calculate the adjusted ADT using the following equation:

$$\text{Adjusted ADT} = (ADT_{cy})(K_c)(K_g)(K_s)$$

Step 3: Look up the adjusted ADT in Table 4-6 for the specific design speed, truck percentage, and shoulder width.

Step 4: Compare the value from Table 4-6 with that calculated from the equation in step 2 above.

Step 5: Select test level based upon the following:

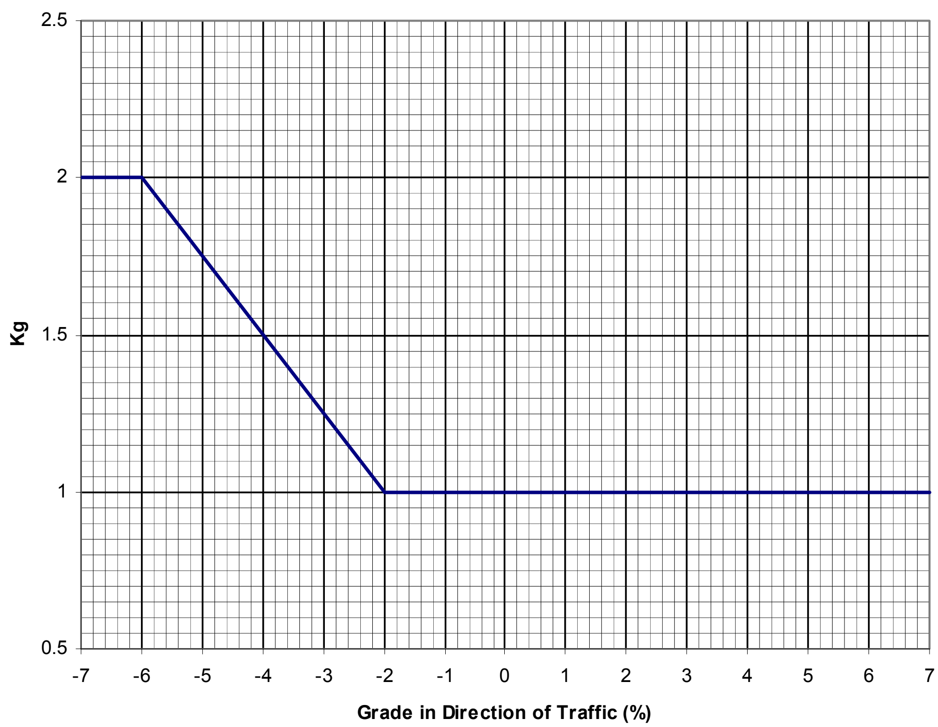
- If the value is less than the value in the TL-4 column, then a TL-2 rail is required, unless the project is on the NHS (refer to Figure 2-2) then a minimum of TL-3 is required.
- If the calculated Adjusted ADT is equal to or greater than the value from the TL-4 column but less than the value from the TL-5 column, then a TL-4 rail is required.
- If the value is equal to or greater than the value from the TL-5 column, then a TL-5 rail is the selected system.

Highway and railroad overpass structures should use an F-shaped barrier or a permanent snow fence attachment in the vicinity of the overpass in order to minimize snow and debris falling onto vehicles below. Should this barrier type be undesirable, the highway or railroad owner should be contacted to determine if an exception is acceptable.

Figure 4-2 K_g and K_c

Grade Traffic Adjustment Factor (K_g)

Curvature Traffic Adjustment Factor (K_c)



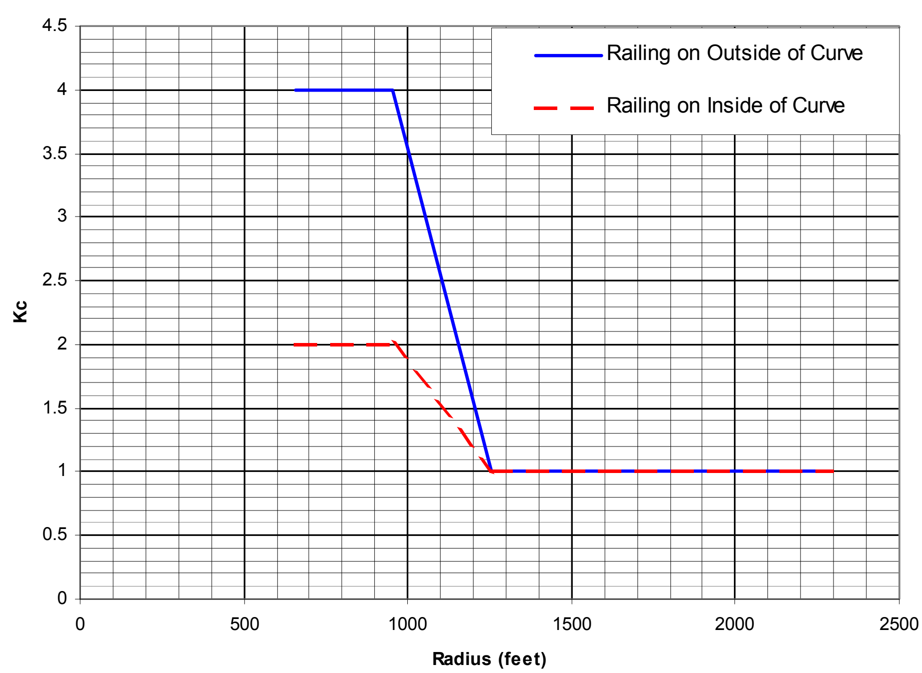


Figure 4-3 K_s

Traffic Adjustment Factor (K_s)

For Deck Height and Under Structure Conditions

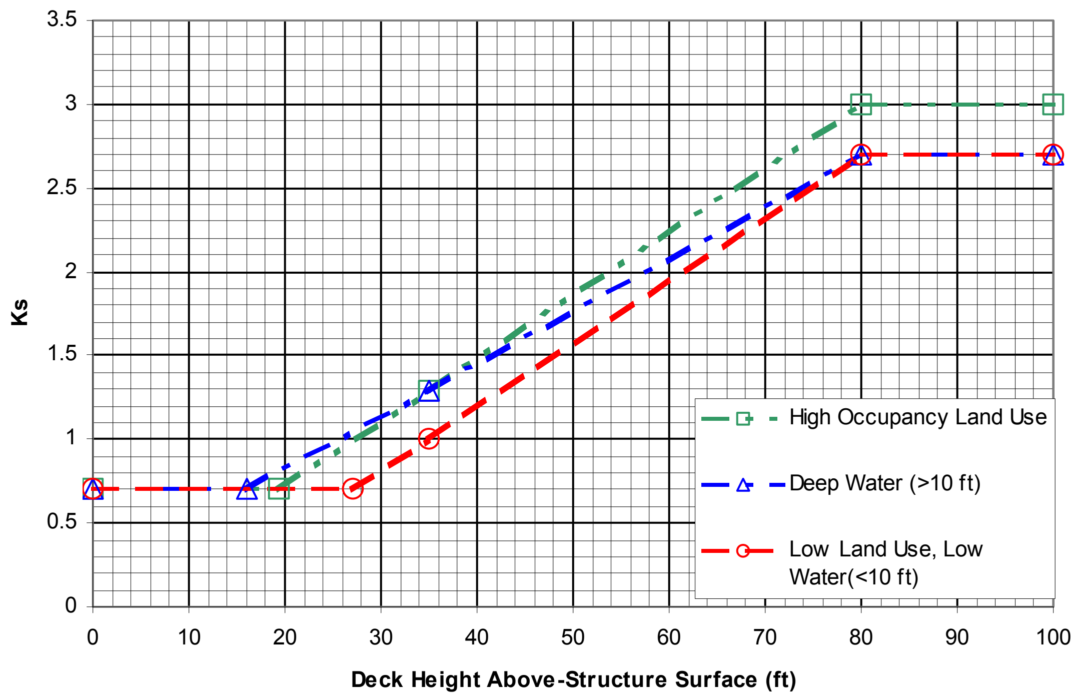


Table 4-6 Bridge Rail Performance Level Selection

Design Speed (mph)	Percent Trucks	Shoulder Width (ft)	Adjusted ADT for which a TL-4 or TL-5 is required: Divided or 5 + lanes TL-4	Divided or 5 + lanes TL-5	Undivided 4 lanes or less TL-4	Undivided 4 lanes or less TL-5	One Way TL-4	One Way TL-5
30	0	0-3	151000	***	144300	***	75500	***
		3-7	283200	***	265200	***	141600	***
		7-12	***	***	***	***	316100	***
	5	0-3	56600	***	48000	***	28300	***
		3-7	90400	***	74600	***	45200	***
		7-12	148300	***	128900	***	74200	***
	10	0-3	23900	179800	19300	147900	12000	89900
		3-7	36500	258300	28800	228700	18300	129200
		7-12	55900	404400	46500	364600	28000	202200
	15	0-3	15100	102900	12100	84500	7600	51500
		3-7	22800	146600	17900	129200	11400	73300
		7-12	34400	228500	28300	205300	17200	114300
	20	0-3	11100	72000	8800	59100	5600	36000
		3-7	16600	102400	13000	90000	8300	51200
		7-12	24900	159200	20400	142900	12500	79600
40	0	0-3	19000	***	14400	***	9500	***
		3-7	24800	***	19000	***	12400	***
		7-12	33100	***	27200	***	16600	***
	5	0-3	14000	280700	10400	202400	7000	140400
		3-7	18000	335100	13400	253800	9000	167600
		7-12	24400	452000	19200	366700	12200	226000
	10	0-3	9800	79700	7100	55600	4900	39900
		3-7	12700	89800	9200	68600	6400	44900
		7-12	16900	132400	12800	102300	8500	66200
	15	0-3	7500	46400	5400	32200	3800	23200
		3-7	9800	51900	7000	39600	4900	26000
		7-12	12900	77600	9600	59400	6500	38800
	20	0-3	6100	32800	4400	22700	3100	16400
		3-7	8000	36500	5600	27900	4000	18300
		7-12	10400	54900	7700	41900	5200	27500
50	0	0-3	6200	***	4200	***	3100	***
		3-7	7200	***	5000	***	3600	***
		7-12	9900	***	7300	***	5000	***
	5	0-3	5500	162200	3700	107000	2800	81100
		3-7	6300	188600	4400	134100	3200	94300
		7-12	8400	247300	6100	171900	4200	123700
	10	0-3	4700	50000	3200	32000	2400	25000
		3-7	5400	61400	3700	41800	2700	30700
		7-12	7200	70600	5100	49300	3600	35300
	15	0-3	4100	29600	2800	18800	2100	14800
		3-7	4800	36700	3300	24800	2400	18400
		7-12	6300	41200	4400	28800	3200	20600
	20	0-3	3700	21000	2500	13300	1900	10500
		3-7	4300	26100	2900	17600	2200	13100
		7-12	5600	29100	3900	20300	2800	14600

Design Speed (mph)	Percent Trucks	Shoulder Width (ft)	Adjusted ADT for which a TL-4 or TL-5 is required					
			Divided or 5 + lanes		Undivided 4 lanes or less		One Way	
			TL-4	TL-5	TL-4	TL-5	TL-4	TL-5
60	0	0-3	3200	***	2000	***	1600	***
		3-7	3600	***	2300	***	1800	***
		7-12	4400	***	2900	***	2200	***
	5	0-3	3000	107300	1900	70300	1500	53700
		3-7	3300	126300	2100	82800	1700	63200
		7-12	4100	158400	2700	105600	2100	79200
	10	0-3	2800	39600	1800	25000	1400	19800
		3-7	3100	47500	2000	29300	1600	23800
		7-12	3900	53100	2500	33700	2000	26600
	15	0-3	2700	24300	1700	15200	1400	12200
		3-7	2900	29300	1900	17800	1500	14700
		7-12	3700	31900	2400	20000	1900	16000
	20	0-3	2500	17500	1600	10900	1300	8800
		3-7	2800	21100	1800	12800	1400	10600
		7-12	3500	22800	2200	14300	1800	11400
70	0	0-3	2200	191400	1300	165000	1100	95700
		3-7	2400	379100	1500	301500	1200	189600
		7-12	2800	***	1700	402400	1400	256400
	5	0-3	2100	63100	1300	42200	1100	31600
		3-7	2300	80000	1400	51600	1200	40000
		7-12	2700	96400	1600	64000	1400	48200
	10	0-3	2000	32100	1200	20000	1000	16100
		3-7	2300	38500	1400	22900	1200	19300
		7-12	2600	42200	1600	26700	1300	21100
	15	0-3	2000	21500	1200	13100	1000	10800
		3-7	2200	25300	1300	14700	1100	12700
		7-12	2600	27000	1600	16900	1300	13500
	20	0-3	1900	16200	1200	9700	1000	8100
		3-7	2100	18900	1300	10800	1100	9500
		7-12	2500	19900	1500	12300	1300	10000

4.4.4 Bicycle Railing

Bicycle bridge rail should be used on those bridges over 20 feet long when either of the following conditions is met:

- The road is signed as a designated bikeway.
- All of the following are true:
  1. High volumes of bicycle traffic are expected.
  2. There is greater than 4 feet and less than 8 feet between the traveled way and the face of traffic rail.

3. AADT is greater than 400.

Bicycle rail need not be used on the sidewalk side of the bridge; instead, pedestrian height rail should be used.

Good engineering judgment must be used to determine whether a bicycle rail is appropriate. The potential for increased bicycle traffic, the geometric configuration of the corridor, along with vehicle speed should be considered. The potential for pedestrian traffic to use an 8 foot wide shoulder on a bridge with a high deck may prompt the need for a barrier taller than traffic-height rail.

Permanent Concrete Barrier Type IIIA may be specified with the bicycle height, two bar steel rail attachment when a bicycle height rail is needed and an F-shaped barrier is selected for the traffic rail. Should the bicycle height attachment be required on the Permanent Concrete Barrier Type IIIB, the one-bar steel rail attachment may be modified to meet the AASHTO geometric requirements, and then shown on the plans.

4.4.5 Reduced Standard Bridge Rail

If the bridge is not on the NHS (refer to Figure 2-2), and the adjusted ADT is less than or equal to half of the maximum allowed for a TL-2 system, a rail may be designed rather than crash-tested. The system may be designed in accordance with AASHTO LRFD Section 13 Appendix A for the TL-2 test condition. The railing must also meet all the geometric requirements for its proposed application found in AASHTO LRFD Section 13.

Consult with the bridge rail technical resource people for examples of recently designed bridge rails.

4.4.6 Aesthetics

Unfortunately, many of the crash-tested rails are often not considered to be aesthetically pleasing. If a TL-2 rail is appropriate, the Texas Classic Rail may be used when aesthetics is a concern. Consideration should also be given to color-galvanizing steel bridge rail to enhance its appearance. The required specification has been developed, along with specific color recommendations. For bridges satisfying the reduced standard criteria in Section 4.4.5, the Structural Designer may design an alternative attractive rail.

4.4.7 Transitions

For projects on the NHS, transitions from approach rail to bridge rail are required to meet the crash-testing conditions of NCHRP Report 350. The current standard details for transitions are based on the Alaskan Transition, which is 350 approved, with some minor modifications suggested by FHWA.

Use the following guidelines for transitions:

- *Steel Bridge Rail:* For transitions on the NHS, use the Concrete Transition Barrier and the Bridge Transition Type 1. The bridge connections and approach guardrail transitions to the standard 2-bar steel bridge rail for bridges not on the NHS may consist of either the Steel Approach Railing or the Concrete Transition Barrier with the Bridge Transition Type 1.

- *Timber Rail:* For approach guardrail transitions and bridge connections to a timber bridge rail, use a shoe attachment with doubled guardrail beam and 3'-1 1/2" post spacing. Either weathering steel or galvanized steel guardrail may be used. If steel backed timber guardrail is used, then the steel should be securely attached to the timber bridge rail.

- *F-Shaped Barrier:* The approach guardrail should be stiffened and rigidly connected to the ends of the standard F-shaped concrete barrier with a Bridge Transition Type 1.

- For one-way bridges on the NHS, the trailing end of the bridge rail need only be connected to the barrier ends with a 6'-3" post spacing and no doubled guardrail beam.

- Regardless of the type of bridge rail selected, if the rail is pedestrian height, then it may be appropriate to have a pedestrian height railing or fence behind all or a portion of the approach railing, depending on site-specific conditions. (i.e., steepness of embankment, height of return wings, etc.)

4.5 Security Fences

The primary purpose of security fencing is to provide for the safety and security of pedestrians, and to prevent objects from being thrown or dropped from bridges to lower roadways, railroads, boat lanes, or occupied property. Certain overpass structures may warrant protective chain link fencing. Refer to the latest version of "A Guide for Protective Screening of Overpass Structures" for more information.

Adding a fence to a bridge structure should not be done routinely. It will increase maintenance responsibilities, and may exacerbate an existing site distance problem. If a fence is used, it should be no higher than 6 feet to avoid limiting inspections with the under-bridge crane.

4.6 Wearing Surfaces

4.6.1 General

All bridges should have a 3 inch bituminous wearing surface plus a standard membrane except as follows:

- Bridges on local and collector roads with simple spans and an AADT less than 1000 should use a 1 inch integral concrete wearing surface.
- Bridges with an AADT greater than or equal to 1000 with grades in excess of 4% up to 8% should use either a 3 inch bituminous wearing surface with a high performance membrane or a 2 inch unreinforced concrete wearing surface.
- Bridges with an AADT over 1000 with grades in excess of 8%, or bridges where higher than usual braking or acceleration forces can be expected, such as at stop signs or exit and entrance ramps, should use a 2 inch unreinforced structural concrete wearing surface.

4.6.2 Descriptions

The types of wearing surfaces are described below:

4.6.2.1 Bituminous Wearing Surface with Membrane

The wearing surface consists of an impervious waterproofing membrane (nominally 1/4” thick) and approximately 3 inches of bituminous pavement of the grades specified on the plans, and placed in layers of the thickness shown in the Specifications.

4.6.2.2 Unreinforced Structural Concrete Wearing Surface

The wearing surface consists of an unreinforced structural concrete wearing surface with a thickness of 2 inches. The concrete used for the wearing surface is Class LP. The structural concrete wearing surface should be treated with protective coating for concrete surfaces.

4.6.2.3 Integral Concrete Wearing Surface

The wearing surface consists of an extra 1 inch cover over the top of the deck reinforcement for a total concrete cover of 3 inches. The extra inch of concrete should be included in the computations as dead load, but should be excluded from the slab section capacity computations. No allowance is made in the computations for future overlays or wearing surfaces. The concrete used for the slab and wearing surface is Class A. The integral concrete wearing surface should be treated with protective coating for concrete surfaces.

4.7 Membranes

Standard waterproofing membrane should be used under bituminous wearing surfaces on most bridge structures. The prequalified list of standard and high performance waterproofing membrane systems can be found on the MaineDOT website at: http://www.state.me.us/mdot/planning/products/membrane.htm. Membrane should also be used on concrete buried structures, placed directly on top of the concrete, and wrapped down one foot along the vertical wall.

High performance membrane should be used in the following situations:

- Butted precast concrete structures without leveling slabs.
- Major structures with high volumes of traffic where maintenance of traffic issues will result in a difficult wearing surface replacement.
- Wearing surface replacements where a rough surface is anticipated (refer to Section 10.2.2 Wearing Surface Replacement/Rehab).

4.8 Deck Joints and Expansion Devices

4.8.1 General

Deck joints add cost to the structure, increase maintenance requirements, and should be avoided whenever possible. Integral abutments should be used (refer to Section 5.4.2, Integral Abutments) or the slab should be carried over the backwall (refer to Section 6.2.2 Decks) whenever possible. The Designer must become familiar with the Standard Details (520 and 521), as well as applicable manufacturer's product information, before specifying an expansion device for a particular project.

In all other cases, deck joints with appropriate expansion devices will be necessary. The choice of which expansion device to use depends upon the movement rating, which is the magnitude of expected expansion and contraction of the structure due to temperature change. The movement rating is the maximum movement from extreme cold to extreme hot, and is calculated as 1-1/4" per 100 feet of bridge expansion length from a fixed bearing. Compression seals are used for a movement rating up to 2-1/2". Gland seals are used for a movement rating up to 3 inches. Finger joints are used up to about 12 inches. Extrapolation of finger joint dimensions or modular joints may be used for larger movement ratings.

Commentary: The expansion rate of 1-1/4” per 100 feet of bridge is based upon the coefficient of expansion for steel. The rate may be used for the determination of the movement rating on all bridge structures either steel or concrete. If a more precise determination of the movement rating for a concrete structure is required, the movement rating may be calculated using the coefficient of expansion for concrete from AASHTO LRFD.

For movement ratings approaching 2-1/2”, either a compression seal or gland seal may be used. Whether or not a gland seal can be used will depend upon the minimum opening supplied by the manufacturer.

Special design consideration is required for skews between 30° and 50° back on the right (skewed either way on the Interstate) because of the hazard of a snowplow blade catching in the joint.

4.8.2 Preformed Elastomeric Joint Seals

Preformed Elastomeric Joint Seals (Compression Seals) should be specified on the plans in accordance with the Standard Details 520 (08-14) and Appendix D Standard Notes Superstructures.

The Designer will calculate the movement rating, and then specify the expansion device based upon that rating to the nearest 1/8”. At fixed bearings that require a deck joint (i.e. non-slab over backwall), a movement rating of 1/2” should be specified, unless an engineering evaluation of the joint geometry indicates the need for a larger value. The maximum opening of any joint is limited to 3-1/2” in the direction of the centerline of the roadway. The Designer should verify that the opening associated with the specified movement rating would not exceed the seal size. Refer to Example 4-1.

Listed in Table 4-7 are the compression seals prequalified for the movement ratings indicated.

Commentary: Table 4-7 was developed based on pressure-deflection tests performed by the University of Maine on samples furnished by the manufacturers. The tested samples were also evaluated for their ability to absorb racking movement. The skews shown in the table are based on that evaluation. This table may also be found at the MaineDOT product approval web page at the following web address: www.state.me.us/mdot/planning/products/compressionseals.htm

Table 4-7 Elastomeric Joint Seal Movement Ratings

Movement Rating (in)	Maximum Expansion Length (ft)	Manufacturer			
		D.S. Brown Company		Watson Bowman Acme Corporation	
		Seal	Maximum Skew	Seal	Maximum Skew
0.500	40	CV1625	40º	WA175	35º
0.625	50	CV1752	35º	WA175	35º
0.750	60	CV2000* or H2001*	35º	WA200	35º
0.875	70	CV2502 or H2505	30º	WA250	30º
1.000	80	CV2502 or H2505	30º	WA250	30º
1.125	90	CV2502 or H2505	30º	WA300	25º
1.250	100	CV3000 or H3000	25º	WA300	25º
1.375	110	CV3000 or H3000	25º	WA350	25º
1.500	120	CV3000 or H3000	25º	WA350	25º
1.625	130	CV3500 or H3500	25º	WA400	25º
1.750	140	CV3500 or H3500	25º	WA500	25º
1.875	150	CV4000 or H4000	25º	WA500	25º
2.000	160	CV4000 or H4000	25º	WA500	25º
2.250	180	CA5001 or H5000	25º	WA500	25º
2.500	200	CA5001 or H5000	25º		

*Use for retrofitting of existing joints only.

Note: The movement rating shown is to be used as the actual movement of the deck joint parallel to the direction of expansion. Although the Standard Details show a movement rating at 45°F to be normal to the centerline of bearings, no reduction in the movement rating will be made for skewed structures. This will compensate for movements in the transverse direction.

The Contractor sets the opening in the field based upon the formula given in Standard Detail 520 (14). The two applicable seals are determined from Table 4-7 for the design movement rating. Refer to Example 4-1 for guidance.

Example 4-1 Compression Seal Design

The calculated movement rating is 1.75 inches. The nominal width is found in the manufacturer's designation, e.g. CV3500 is a 3-1/2" seal, and WA500 is a 5 inch seal. This width is based upon the relaxed dimension of the seal. The 0.85 multiplier is used to assure the seal is always in compression. The WA500 from Watson Bowman is tried to determine its applicability to the deck joint.

Step 1: Find the opening at 45°F, X.
X = (0.85 x nominal width) – (1/2 x movement rating)
X = (0.85 x 5) – 1/2 (1.75) = 3.375" at 45°F (*refer to Note 4, Standard Detail 520 (14)*)

Step 2: Find the maximum opening
Max opening = 3.375 + 1/2(1.75) = 4.25" at -30°F

Since this exceeds the maximum allowable opening of 3-1/2", a different manufacturer's seal should be used or a special sliding plate configuration will be necessary. Therefore, try the DS Brown seal.

Step 3: Repeat previous steps for another seal.
X = (0.85 x 3.5) – 1/2 (1.75) = 2.10" at 45°F
Maximum opening = 2.10 + 1/2(1.75) = 2.98" at -30°F

This is less than 3-1/2". Thus, a compression seal may be used, either with or without sliding plates. Far more frequently the Contractor elects to avoid the sliding plates configuration and uses the compression seal.

4.8.3 Gland Seals

Gland Seals should be specified on the plans in accordance with Standard Details 520 (01-07) and Appendix D Standard Notes Superstructures.

The 4 inch nominal gland seal is the only size that is allowed by MaineDOT. The minimum opening for a gland seal is set at 1/2". This differs from the manufacturer's recommendation of 0 inches minimum. Also, the maximum allowable opening allowed by MaineDOT is set at 3-1/2". Therefore, when the Designer uses a 4 inch nominal gland seal, the actual maximum movement rating allowed will be 3 inches (3-1/2" minus 1/2").

The maximum allowed skew for a gland seal is 45°. This is limited by the racking ability of the seal.

4.8.4 Finger Joints

Finger joints should be specified on the plans in accordance with Standard Details 521(01-11) and Appendix D Standard Notes Superstructures. Standard Detail 521(10) provides a table that specifies dimensions required for a given span length and skew.

This is the expansion device most commonly used for bridges with a movement rating of greater than 3 inches. If bicycle and/or pedestrian traffic is a major concern, consideration should be given to placing a sliding plate on top where needed to cover the opening.

To collect the roadway drainage through the finger joint, a curtain or trough system must be used. The curtain system (Figure 4-4) protects the girder by placing neoprene curtains at the end of each girder, and dumping the water diffusely on a protected bridge seat, which is periodically cleaned by Bridge Maintenance. The curtain system is usually preferred because of the easy access for maintenance, and its effectiveness in protecting the girder by eliminating drains which may plug.

The trough system (Figure 4-5) collects the water and directs it via a drain to a specific location. Debris that collects in troughs should be cleaned out by Bridge Maintenance before it accumulates to the point where it is too heavy for the trough to support. Although the curtain system is preferred, the trough system may be necessary if adjacent buildings or other site features must be protected from diffuse spray.

4.8.5 Modular Joints

Modular joints are usually quite expensive compared to other expansion devices, and have had a poor record in performance and maintenance. They should be used only under special circumstances with permission from the Engineer of Design, such as when using a curtain or trough system becomes problematic, and the additional cost can be justified. Modular joints should be specified on the plans in accordance with Standard Specifications Section 522 – Expansion Devices - Modular. Only gland type seals are permitted. The Designer will provide the anticipated movement rating to the manufacturer, who will design the modular joint. The model selection should be based on data from Watson-Bowman-Acme and/or D. S. Brown.

The dimensions for the block-out must be determined, shown on the design drawings, and verified by the manufacturer. It is suggested that 1’-6” be used for movements up to and including 10 inches. For movements larger than 10 inches, the block-out width and the backwall width must be increased by 4 inches for each additional 3 inches of movement or fraction thereof. The dimension of 1’-3” between the face of backwall and centerline of bearings can be used for movements up to and including 6 inches. For movements larger than 6 inches this dimension must be increased 3 inches for each additional 3 inches of movement or fraction thereof.

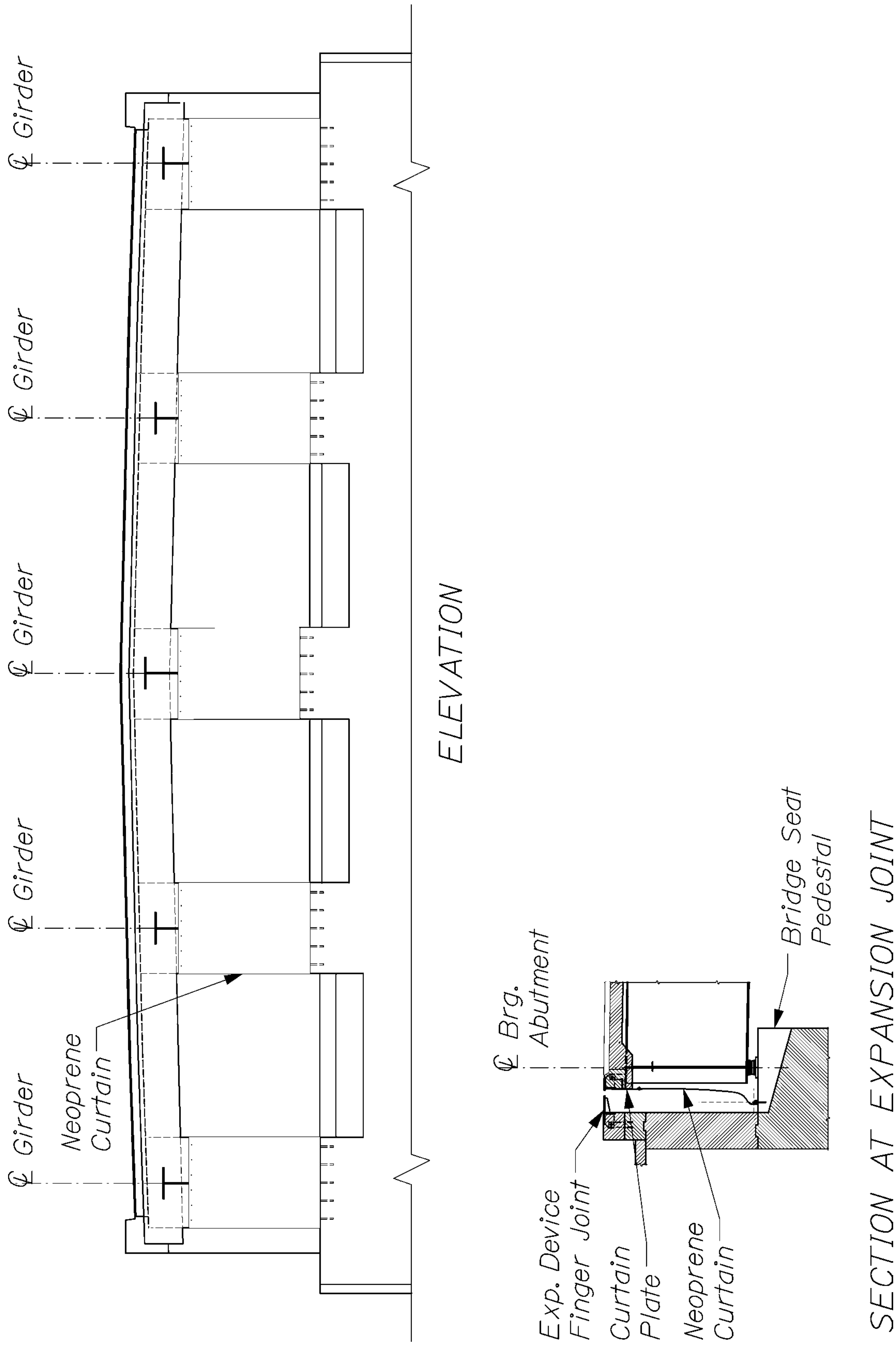


Figure 4-4 Curtain System

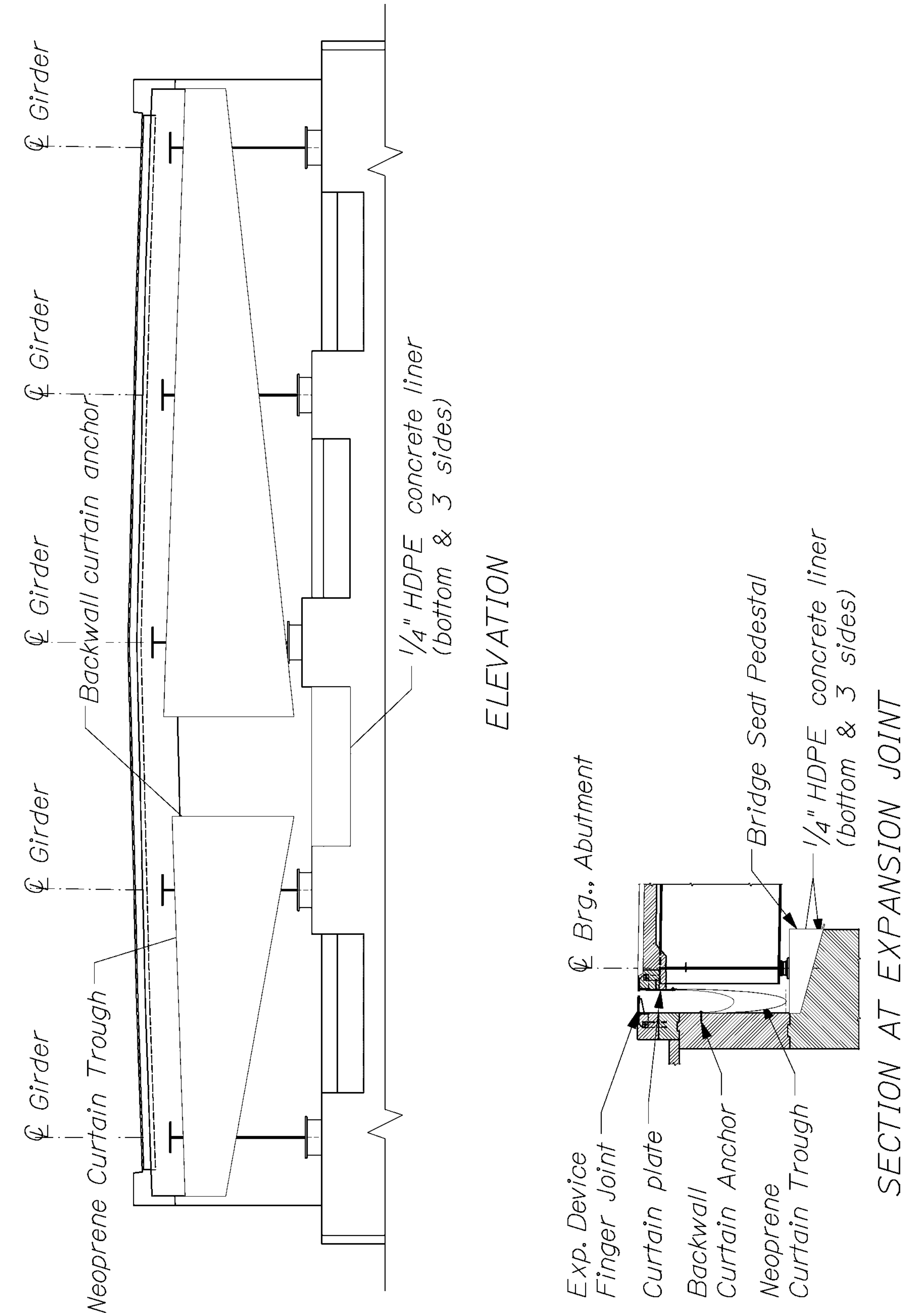


Figure 4-5 Trough System

4.8.6 Design/Contract Drawings Presentation

The selected expansion device (compression seal, gland seal, finger joint, etc.) should be shown in the body of the drawing, commonly on the superstructure slab view, as well as included in the estimate sheet.

Movement ratings for all expansion devices should be shown on the drawing. A design drawing with a compression seal should also show a temperature adjustment chart. Other expansion device adjustments are calculated in the field through a formula in the Standard Details, and need not be shown on the plans.

Special attention should be paid to unique deck joint situations, such as finger joints beyond the standard detail largest size, modular joints, and gland seal joints that have the potential of exceeding the 3-1/2” opening limit.

4.9 Drains

4.9.1 Design

When required, bridge drains should be used as detailed in Standard Details 502. All modifications to the Standard Details must be approved by the Engineer of Design. If a custom drain is needed, the following criteria should be met:

- The minimum width dimension for the downspout should be 8 inches whenever possible, to help avoid clogging.
- The opening for the drain should be kept out of the wheel path.
- The grating should be bicycle-friendly (perpendicular to traffic).

Bridge drain spacing should begin at a convenient spot on the bridge, i.e. the low end, and progress across the structure. Drains should be placed so that splash onto substructure units does not occur. Preferably, drains should not be placed within 10 feet of a pier or abutment. For overpasses, drains should not be placed over the roadway or the railroad tracks. At the vertex of a sag vertical curve, provide one extra drain on either side of the drain at the low point.

When steep grades are involved, consideration should be given to closely spacing two drains at the low end of a bridge to minimize runoff erosion at the abutment from drain overflow. Approaches to the bridge should be designed to handle runoff from the bridge.

At the ends of concrete barriers, wingwalls, and at other locations where roadway runoff is likely to concentrate, erosion protection should be provided on side slopes by the use of sod or riprap down spouts, catch basins and outlet culverts, or other approved means of erosion control. Concrete splash blocks should be used under the discharge of deck drains on slopes not otherwise protected by either riprap or slope pavement.

4.9.2 Use of Standard Details

Standard Details Section 502 has three standard types of bridge drains. Drain Type A has a 2'-9" long by 1 foot wide grate with an 8 inch by 12 inch downspout. The length of the grate is based on a 3 foot over hang with a 12 inch or 16 inch wide beam flange. The length of the grate may need to be increased for beams with wider flanges or larger overhangs.

Drain Type B consists of a 1-4" by 1 foot grate with a 1 foot by 1 foot downspout. This drain should be used on bridges with narrow shoulders. Typically, these drains are used on bridges with a curb-to-curb width of 28 feet or less with shoulders 2 feet wide or narrower. Assuming a 12 inch wide beam flange, the maximum overhang dimension is 1'-11".

Drain Type C consists of a 1 foot by 1 foot grate with and a straight 1 foot by 1 foot downspout. This drain is the least prone to clogging. Typically, this drain would be used next to sidewalks or on bridges with somewhat large overhangs. Assuming a 12 inch wide flange and a 1'-8" wide curb, the minimum overhang dimension is 3'-7". One disadvantage with this drain is aesthetics, since the drain is on the outside of the beam and not hidden from view.

A standard drain has not been developed for butted precast concrete voided slabs and box beams. The preferred drainage system for this structure type is no drains at all. To avoid drains, the shoulder must be wide enough or the bridge length short enough to preclude the need for drains. If drains are needed, an opening in the curb through to the fascia is required. Then the fascia must be protected from the salt-laden water.

4.9.3 Bridge Drain Spacing Tables

The maximum bridge drain spacing can be determined using Table 4-8 through Table 4-14 for drain Type A and Table 4-15 through Table 4-28 for drain Types B and C. The maximum drain spacing is 300 feet. Consider the following exceptions when using the tables:

- Bridges over 200 feet in length will require at least one drain per drainage area located at the low end.

- o If a vertical curve is on the bridge, the tables cannot be used.
- o Consideration should be given to reducing the bridge drain spacing from what the tables allow for bridges with drainage lengths over 200 feet. Long flow lengths with few drains should be avoided due to potential hazards if some drains become clogged.

The information needed for the proper use of the tables includes:

- o Cross-slope of the bridge and whether or not the elevated shoulder of a superelevated section is included in the drainage area
- o Grade of the bridge
- o Number of lanes to be drained
- o Shoulder width
- o Bridge length

Commentary: The procedure used to develop these tables is referenced in FHWA HEC 12 and FHWA HEC 21. A Q10 storm frequency was assumed with a rainfall intensity of 5 inches per hour. The drain spacing tables are based on the assumption that the bridge has a constant grade. If a vertical curve is on the bridge, the tables cannot be used. The Designer should refer to HEC 21 for the design procedure for a bridge on a vertical curve.

Table 4-8 Bridge Drain Type A

Maximum Bridge Drain Spacing
Normal Crown Deck
2% Cross Slope (0.24”/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	1	20	20	45	45	88	85	83	80	142	127	208	171
	2	13	13	31	31	55	55	53	53	85	76	130	107
1	1	22	22	62	62	125	120	117	113	201	179	295	240
	2	13	13	34	34	55	52	69	66	121	107	184	150
1.5	1	27	27	76	76	153	146	144	138	246	218	361	293
	2	15	15	42	42	87	84	84	81	148	131	226	183
2	1	32	32	87	87	176	169	166	159	285	252	417	338
	2	17	17	48	48	101	96	97	93	171	151	260	211
2.5	1	35	35	98	97	197	189	186	178	318	281	466	377
	2	19	19	54	54	113	108	109	104	191	169	291	236
3	1	39	39	107	107	216	207	203	195	348	308	510	413
	2	21	21	59	59	123	118	119	114	209	185	319	258
3.5	1	42	42	115	115	233	223	220	210	376	333	551	439
	2	23	23	64	64	133	128	129	123	226	200	345	275
4	1	45	45	123	123	250	239	235	225	402	356	589	460
	2	24	24	69	69	143	136	138	132	241	213	368	287
4.5	1	48	48	131	131	265	253	249	238	427	371	625	478
	2	26	26	73	73	151	145	146	140	256	223	391	299
5	1	50	50	138	138	279	267	263	251	450	385	659	495
	2	27	27	77	77	159	152	154	147	270	231	412	309

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-9 Bridge Drain Type A

Maximum Bridge Drain Spacing
Superelevated Deck Excluding Elevated Shoulder
2% Cross Slope (0.24”/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	13	13	31	31	55	55	53	53	85	76	130	107
	4	9	9	20	20	36	36	36	36	56	56	81	81
1	2	13	13	34	34	71	68	69	66	121	107	184	150
	4	9	9	20	20	38	37	38	36	67	60	105	86
1.5	2	15	15	42	42	87	84	84	81	148	131	226	183
	4	9	9	22	22	47	45	46	44	82	73	129	105
2	2	17	17	48	48	101	96	97	93	171	151	260	211
	4	9	9	26	26	54	52	53	51	95	84	149	121
2.5	2	19	19	54	54	113	108	109	104	191	169	291	236
	4	10	10	29	29	61	58	60	57	106	94	166	135
3	2	21	21	59	59	123	118	119	114	209	185	319	258
	4	11	11	31	31	66	64	65	62	116	103	182	147
3.5	2	23	23	64	64	133	128	129	123	226	200	345	275
	4	12	12	34	34	72	69	70	67	125	111	197	157
4	2	24	24	69	69	143	136	138	132	241	213	368	287
	4	13	13	36	36	77	73	75	72	134	119	210	164
4.5	2	26	26	73	73	151	145	146	140	256	223	391	299
	4	13	13	39	38	81	78	80	76	142	124	223	171
5	2	27	27	77	77	159	152	154	147	270	231	412	309
	4	14	14	41	41	86	82	84	81	150	128	235	177

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-10 Bridge Drain Type A

Maximum Bridge Drain Spacing
Superelevated Deck Including Elevated Shoulder
2% Cross Slope (0.24"/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	13	13	31	31	55	55	53	53	84	84	118	118
	4	9	9	20	20	36	36	36	36	56	56	81	81
1	2	13	13	31	31	62	60	59	56	101	89	147	120
	4	9	9	20	20	36	36	36	36	60	56	92	81
1.5	2	14	14	38	38	76	73	72	69	123	109	180	147
	4	9	9	21	21	44	42	42	40	74	66	113	92
2	2	16	16	44	44	88	84	83	79	142	126	208	169
	4	9	9	24	24	50	48	49	47	85	76	130	106
2.5	2	18	18	49	49	99	94	93	89	159	141	233	189
	4	10	10	27	27	56	54	54	52	95	84	146	118
3	2	19	19	53	53	108	103	102	97	174	154	255	206
	4	10	10	30	30	62	59	60	57	105	92	159	129
3.5	2	21	21	58	58	117	112	110	105	188	166	276	220
	4	11	11	32	32	67	64	64	62	113	100	172	137
4	2	22	22	62	62	125	119	117	112	201	178	295	230
	4	12	12	34	34	71	68	69	66	121	107	184	144
4.5	2	24	24	65	65	132	127	125	119	213	186	313	239
	4	13	13	36	36	76	72	73	70	128	111	195	150
5	2	25	25	69	69	139	133	131	126	225	192	329	247
	4	13	13	38	38	80	76	77	74	135	115	206	155

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-11 Bridge Drain Type A

Maximum Bridge Drain Spacing
Superelevated Deck Excluding Elevated Shoulder
4% Cross Slope (0.48"/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	36	36	83	83	160	154	155	149	272	242	414	340
	4	23	23	54	54	98	98	97	97	151	135	237	194
1	2	38	38	109	109	227	217	219	210	384	341	586	477
	4	23	23	58	58	122	117	120	115	213	189	335	273
1.5	2	47	47	134	133	278	266	268	257	470	417	718	567
	4	24	24	71	71	150	143	147	141	261	232	410	324
2	2	54	54	154	154	321	307	310	296	543	465	829	623
	4	28	28	82	82	173	165	169	162	302	258	474	356
2.5	2	61	61	173	172	359	336	346	324	607	500	927	666
	4	32	32	91	91	193	181	189	177	337	278	529	380
3	2	66	66	189	189	393	357	379	345	665	529	1015	699
	4	35	35	100	100	212	192	208	189	370	294	580	399
3.5	2	72	72	204	201	424	375	410	362	719	552	1096	724
	4	37	37	108	106	229	202	224	198	399	307	626	414
4	2	77	77	218	210	454	391	438	377	768	571	1172	745
	4	40	40	116	111	244	210	240	206	427	317	670	425
4.5	2	81	81	231	219	481	404	465	390	815	587	1243	760
	4	42	42	123	116	259	218	254	214	453	326	710	434
5	2	86	86	244	227	507	416	490	401	859	600	1310	772
	4	45	45	129	120	273	224	268	220	477	333	749	441

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-12 Bridge Drain Type A

Maximum Bridge Drain Spacing
Superelevated Deck Including Elevated Shoulder
4% Cross Slope (0.48"/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	36	36	83	83	148	148	145	145	227	227	331	272
	4	23	23	54	54	98	98	97	97	153	153	219	219
1	2	36	36	98	98	198	190	187	179	320	284	469	382
	4	23	23	55	54	113	109	110	105	192	171	293	238
1.5	2	44	44	120	120	243	233	229	219	392	347	574	454
	4	24	24	67	67	139	133	134	128	235	208	359	283
2	2	50	50	139	139	281	269	264	253	453	387	663	498
	4	27	27	77	77	160	153	155	148	272	232	414	311
2.5	2	56	56	155	155	314	294	295	276	506	417	741	532
	4	30	30	86	86	179	168	173	162	304	250	463	333
3	2	62	62	170	170	344	312	324	294	554	441	812	559
	4	33	33	95	94	196	179	190	172	333	264	507	349
3.5	2	67	67	184	181	371	328	349	309	599	460	877	580
	4	36	36	102	100	212	188	205	181	359	276	548	362
4	2	71	71	196	189	397	342	374	322	640	476	938	596
	4	38	38	109	105	227	195	219	189	384	286	586	372
4.5	2	76	76	208	197	421	354	396	333	679	489	994	608
	4	41	41	116	109	241	202	232	195	407	294	622	380
5	2	80	80	220	204	444	364	418	342	716	500	1048	617
	4	43	43	122	113	254	208	245	201	430	300	655	386

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-13 Bridge Drain Type A

Maximum Bridge Drain Spacing
Superelevated Deck Excluding Elevated Shoulder
6% Cross Slope (0.72”/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	65	65	152	152	316	303	305	293	535	477	816	668
	4	42	42	97	97	176	176	173	173	297	265	466	382
1	2	76	76	215	215	446	428	431	413	756	663	1153	894
	4	42	42	114	114	240	230	236	226	420	369	659	511
1.5	2	93	93	263	263	547	510	528	492	926	759	1413	1010
	4	48	48	139	139	294	274	289	269	514	422	807	577
2	2	107	107	304	300	631	560	610	541	1069	826	1631	1085
	4	56	56	161	159	340	302	334	296	594	459	932	620
2.5	2	119	119	340	324	706	599	682	578	1196	873	1824	1134
	4	62	62	180	171	380	323	373	317	664	485	1042	648
3	2	131	131	372	343	773	629	747	607	1310	907	1998	1164
	4	68	68	197	182	416	339	409	332	728	504	1142	665
3.5	2	141	139	402	360	835	653	806	630	1415	930	2158	1180
	4	73	72	213	190	450	351	441	345	786	517	1233	674
4	2	151	146	430	374	893	671	862	648	1512	946	2307	1184
	4	79	76	227	198	481	361	472	354	840	525	1318	677
4.5	2	160	152	456	385	947	685	914	661	1604	955	2447	1179
	4	83	79	241	204	510	369	500	362	891	530	1398	674
5	2	169	157	480	395	998	695	964	671	1691	958	2579	1167
	4	88	82	254	209	538	374	527	367	939	532	1474	667

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-14 Bridge Drain Type A

Maximum Bridge Drain Spacing
Superelevated Deck Including Elevated Shoulder
6% Cross Slope (0.72”/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	65	65	149	149	276	265	260	250	446	397	652	535
	4	42	42	97	97	176	176	173	173	274	274	408	334
1	2	70	70	193	193	391	374	368	352	630	553	923	715
	4	42	42	107	107	223	214	216	206	378	332	577	447
1.5	2	86	86	237	236	478	446	450	420	772	633	1130	808
	4	46	46	132	131	273	255	264	246	463	380	706	505
2	2	99	99	273	270	552	490	520	462	891	688	1305	868
	4	53	53	152	150	316	280	305	271	535	413	816	543
2.5	2	111	111	306	291	618	524	581	493	996	727	1459	907
	4	60	60	170	162	353	300	341	289	598	436	912	567
3	2	122	122	335	309	677	551	637	518	1091	756	1598	931
	4	65	65	186	172	387	315	373	304	655	453	999	582
3.5	2	131	129	362	324	731	571	688	537	1179	775	1726	944
	4	71	70	201	180	418	326	403	315	707	465	1079	590
4	2	140	135	387	336	781	587	735	553	1260	788	1845	947
	4	76	73	215	187	446	335	431	324	756	473	1153	592
4.5	2	149	141	410	347	829	599	780	564	1337	796	1957	944
	4	80	76	228	193	474	342	457	331	802	477	1223	590
5	2	157	146	432	355	874	609	822	573	1409	798	2063	934
	4	84	79	240	197	499	348	482	336	845	479	1290	584

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-15 Bridge Drain Type B

Maximum Bridge Drain Spacing
Normal Crown Deck
2% Cross Slope (0.24”/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	1	20	20	45	45	88	62	83	59	142	87	208	111
	2	13	13	31	31	55	55	53	53	85	52	130	69
1	1	22	21	62	50	125	86	117	81	201	118	295	151
	2	13	13	34	31	71	49	69	47	121	71	184	94
1.5	1	27	26	76	61	153	104	144	98	246	143	361	182
	2	15	14	42	34	87	59	84	57	148	86	226	114
2	1	32	30	87	70	176	119	166	112	285	164	417	209
	2	17	16	48	39	101	68	97	66	171	98	260	131
2.5	1	35	34	98	78	197	133	186	125	318	183	466	233
	2	19	18	54	43	113	76	109	73	191	110	291	145
3	1	39	37	107	85	216	145	203	136	348	199	510	254
	2	21	20	59	47	123	83	119	80	209	120	319	159
3.5	1	42	40	115	92	233	156	220	147	376	215	551	270
	2	23	21	64	51	133	89	129	86	226	129	345	169
4	1	45	43	123	98	250	167	235	157	402	229	589	282
	2	24	23	69	55	143	95	138	92	241	138	368	176
4.5	1	48	45	131	104	265	177	249	166	427	239	625	293
	2	26	24	73	58	151	101	146	97	256	144	391	183
5	1	50	48	138	110	279	186	263	175	450	248	659	303
	2	27	26	77	61	159	106	154	103	270	149	412	189

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-16 Bridge Drain Type B

Maximum Bridge Drain Spacing
Superelevated Deck Excluding Elevated Shoulder
2% Cross Slope (0.24"/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	13	13	31	31	55	55	53	53	85	52	130	69
	4	9	9	20	20	36	36	36	36	47	29	74	40
1	2	13	13	34	31	71	55	69	53	121	71	184	94
	4	9	9	20	20	38	36	38	36	67	39	105	54
1.5	2	15	14	42	34	87	59	84	57	148	86	226	114
	4	9	9	22	20	47	36	46	36	82	48	129	65
2	2	17	16	48	39	101	68	97	66	171	98	260	131
	4	9	9	26	21	54	37	53	36	95	55	149	75
2.5	2	19	18	54	43	113	76	109	73	191	110	291	145
	4	10	9	29	23	61	41	60	40	106	61	166	83
3	2	21	20	59	47	123	83	119	80	209	120	319	159
	4	11	10	31	25	66	45	65	44	116	66	182	91
3.5	2	23	21	64	51	133	89	129	86	226	129	345	169
	4	12	11	34	27	72	48	70	47	125	72	197	96
4	2	24	23	69	55	143	95	138	92	241	138	368	176
	4	13	12	36	29	77	51	75	50	134	76	210	101
4.5	2	26	24	73	58	151	101	146	97	256	144	391	183
	4	13	13	39	31	81	54	80	53	142	80	223	105
5	2	27	26	77	61	159	106	154	103	270	149	412	189
	4	14	13	41	32	86	57	84	56	150	83	235	108

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-17 Bridge Drain Type B

Maximum Bridge Drain Spacing
Superelevated Deck Including Elevated Shoulder
2% Cross Slope (0.24”/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	13	13	31	31	55	55	53	53	84	84	118	118
	4	9	9	20	20	36	36	36	36	43	26	65	35
1	2	13	13	31	31	62	55	59	53	101	84	147	118
	4	9	9	20	20	36	36	36	36	60	36	92	47
1.5	2	14	13	38	30	76	52	72	49	123	84	180	118
	4	9	9	21	20	44	30	42	36	74	43	113	57
2	2	16	15	44	35	88	60	83	56	142	84	208	118
	4	9	9	24	19	50	34	49	36	85	49	130	65
2.5	2	18	17	49	39	99	66	93	62	159	91	233	118
	4	10	9	27	22	56	38	54	37	95	55	146	73
3	2	19	18	53	43	108	72	102	68	174	100	255	127
	4	10	10	30	24	62	41	60	40	105	60	159	79
3.5	2	21	20	58	46	117	78	110	73	188	107	276	135
	4	11	11	32	26	67	45	64	43	113	64	172	84
4	2	22	21	62	49	125	83	117	78	201	115	295	141
	4	12	11	34	27	71	48	69	46	121	69	184	88
4.5	2	24	23	65	52	132	88	125	83	213	120	313	147
	4	13	12	36	29	76	50	73	49	128	72	195	92
5	2	25	24	69	55	139	93	131	88	225	124	329	151
	4	13	13	38	31	80	53	77	51	135	74	206	95

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-18 Bridge Drain Type B

Maximum Bridge Drain Spacing
Superelevated Deck Excluding Elevated Shoulder
4% Cross Slope (0.48”/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	36	36	83	83	160	112	155	109	272	164	414	219
	4	23	23	54	54	98	98	97	97	151	91	237	125
1	2	38	37	109	88	227	155	219	150	384	225	586	299
	4	23	23	58	54	122	98	120	97	213	125	335	171
1.5	2	47	45	134	108	278	188	268	181	470	272	718	352
	4	24	23	71	57	150	101	147	99	261	151	410	201
2	2	54	52	154	124	321	216	310	208	543	302	829	385
	4	28	27	82	66	173	116	169	114	302	168	474	220
2.5	2	61	58	173	138	359	235	346	227	607	324	927	410
	4	32	30	91	73	193	127	189	124	337	180	529	234
3	2	66	63	189	151	393	250	379	241	665	342	1015	430
	4	35	33	100	80	212	135	208	132	370	190	580	246
3.5	2	72	68	204	160	424	262	410	253	719	357	1096	445
	4	37	35	108	85	229	141	224	139	399	198	626	254
4	2	77	73	218	168	454	273	438	264	768	369	1172	457
	4	40	38	116	89	244	147	240	144	427	205	670	261
4.5	2	81	77	231	175	481	282	465	272	815	379	1243	466
	4	42	40	123	92	259	152	254	149	453	210	710	266
5	2	86	81	244	181	507	290	490	280	859	387	1310	473
	4	45	42	129	96	273	156	268	153	477	215	749	270

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-19 Bridge Drain Type B

Maximum Bridge Drain Spacing
Superelevated Deck Including Elevated Shoulder
4% Cross Slope (0.48"/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	36	36	83	83	148	148	145	145	226	137	331	175
	4	23	23	54	54	80	56	77	54	136	82	207	109
1	2	36	36	98	80	198	148	187	128	320	187	469	239
	4	23	23	55	54	113	78	110	75	192	112	293	149
1.5	2	44	42	120	97	243	164	229	155	392	227	574	282
	4	24	23	67	54	139	94	134	91	235	136	359	176
2	2	50	48	139	111	281	189	264	178	453	252	663	308
	4	27	26	77	62	160	108	155	104	272	151	414	192
2.5	2	56	54	155	124	314	206	295	194	506	270	741	328
	4	30	29	86	69	179	118	173	114	304	162	463	205
3	2	62	59	170	136	344	219	324	206	554	285	812	344
	4	33	32	95	75	196	125	190	121	333	171	507	215
3.5	2	67	63	184	144	371	230	349	216	599	297	877	356
	4	36	34	102	80	212	131	205	127	359	178	548	222
4	2	71	68	196	151	397	239	374	225	640	307	938	365
	4	38	36	109	84	227	136	219	132	384	184	586	228
4.5	2	76	72	208	157	421	247	396	232	679	315	994	373
	4	41	39	116	87	241	141	232	136	407	189	622	233
5	2	80	76	220	163	444	254	418	239	716	322	1048	378
	4	43	41	122	90	254	145	245	140	430	193	655	236

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-20 Bridge Drain Type B

Maximum Bridge Drain Spacing
Superelevated Deck Excluding Elevated Shoulder
6% Cross Slope (0.72”/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	65	65	152	125	316	220	305	213	535	321	816	428
	4	42	42	97	97	176	176	173	173	297	178	466	244
1	2	76	72	215	174	446	304	431	294	756	436	1153	559
	4	42	42	114	97	240	176	236	173	420	242	659	320
1.5	2	93	88	263	211	547	360	528	347	926	496	1413	627
	4	48	46	139	112	294	194	289	190	514	275	807	358
2	2	107	102	304	240	631	394	610	381	1069	537	1631	671
	4	56	53	161	127	340	212	334	208	594	298	932	383
2.5	2	119	113	340	259	706	420	682	406	1196	566	1824	700
	4	62	59	180	137	380	226	373	222	664	315	1042	400
3	2	131	124	372	275	773	441	747	425	1310	587	1998	717
	4	68	65	197	145	416	237	409	233	728	326	1142	410
3.5	2	141	132	402	287	835	457	806	441	1415	602	2158	726
	4	73	69	213	152	450	246	441	241	786	334	1233	415
4	2	151	138	430	298	893	469	862	453	1512	611	2307	728
	4	79	72	227	158	481	252	472	248	840	339	1318	416
4.5	2	160	144	456	307	947	478	914	462	1604	616	2447	725
	4	83	75	241	163	510	258	500	253	891	342	1398	414
5	2	169	149	480	315	998	485	964	469	1691	618	2579	717
	4	88	77	254	167	538	261	527	256	939	343	1474	410

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-21 Bridge Drain Type B

Maximum Bridge Drain Spacing
Superelevated Deck Including Elevated Shoulder
6% Cross Slope (0.72”/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	65	65	149	149	276	193	260	182	446	268	652	342
	4	42	42	76	62	158	110	152	106	267	161	408	214
1	2	70	67	193	156	391	266	368	251	630	364	923	447
	4	42	42	107	87	223	152	216	147	378	218	577	280
1.5	2	86	82	237	190	478	315	450	296	772	413	1130	502
	4	46	44	132	106	273	180	264	174	463	248	706	314
2	2	99	94	273	216	552	345	520	325	891	447	1305	537
	4	53	51	152	120	316	197	305	190	535	268	816	336
2.5	2	111	105	306	233	618	368	581	346	996	472	1459	560
	4	60	57	170	130	353	210	341	203	598	283	912	350
3	2	122	115	335	247	677	386	637	363	1091	489	1598	573
	4	65	62	186	137	387	220	373	213	655	294	999	358
3.5	2	131	123	362	259	731	399	688	376	1179	501	1726	581
	4	71	66	201	144	418	228	403	220	707	301	1079	363
4	2	140	128	387	268	781	410	735	386	1260	509	1845	582
	4	76	69	215	149	446	234	431	226	756	306	1153	364
4.5	2	149	134	410	276	829	419	780	394	1337	514	1957	580
	4	80	72	228	154	474	239	457	231	802	308	1223	362
5	2	157	138	432	283	874	425	822	400	1409	515	2063	573
	4	84	74	240	157	499	243	482	234	845	309	1290	358

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-22 Bridge Drain Type C

Maximum Bridge Drain Spacing
Normal Crown Deck
2% Cross Slope (0.24"/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	1	20	20	45	45	88	53	83	50	142	72	208	92
	2	13	13	31	31	55	55	53	53	85	43	130	57
1	1	22	20	62	45	125	71	117	67	201	97	295	122
	2	13	13	34	31	71	55	69	53	121	58	184	77
1.5	1	27	24	76	52	153	86	144	81	246	116	361	147
	2	15	13	42	31	87	55	84	53	148	70	226	92
2	1	32	27	87	60	176	98	166	92	285	133	417	168
	2	17	15	48	33	101	56	97	54	171	80	260	105
2.5	1	35	30	98	66	197	109	186	103	318	148	466	186
	2	19	16	54	37	113	62	109	60	191	89	291	116
3	1	39	33	107	72	216	119	203	112	348	161	510	203
	2	21	18	59	40	123	68	119	66	209	97	319	127
3.5	1	42	36	115	78	233	128	220	120	376	173	551	215
	2	23	19	64	43	133	73	129	71	226	104	345	134
4	1	45	38	123	83	250	137	235	128	402	185	589	225
	2	24	21	69	46	143	78	138	75	241	111	368	140
4.5	1	48	40	131	88	265	144	249	136	427	192	625	233
	2	26	22	73	49	151	83	146	80	256	115	391	146
5	1	50	43	138	93	279	152	263	143	450	199	659	241
	2	27	23	77	51	159	87	154	84	270	120	412	151

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-23 Bridge Drain Type C

Maximum Bridge Drain Spacing
Superelevated Deck Excluding Elevated Shoulder
2% Cross Slope (0.24"/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	13	13	31	31	55	55	53	53	85	43	130	57
	4	9	9	20	20	36	36	36	36	47	24	74	33
1	2	13	13	34	31	71	55	69	53	121	58	184	77
	4	9	9	20	20	38	36	38	36	67	32	105	44
1.5	2	15	13	42	31	87	55	84	53	148	70	226	92
	4	9	9	22	20	47	36	46	36	82	39	129	52
2	2	17	15	48	33	101	56	97	53	171	80	260	105
	4	9	9	26	20	54	36	53	36	95	44	149	60
2.5	2	19	16	54	37	113	62	109	60	191	89	291	116
	4	10	8	29	20	61	36	60	36	106	49	166	66
3	2	21	18	59	40	123	68	119	66	209	97	319	127
	4	11	9	31	21	66	37	65	36	116	54	182	72
3.5	2	23	19	64	43	133	73	129	71	226	104	345	134
	4	12	10	34	23	72	39	70	39	125	58	197	77
4	2	24	21	69	46	143	78	138	75	241	111	368	140
	4	13	11	36	24	77	42	75	41	134	62	210	80
4.5	2	26	22	73	49	151	83	146	80	256	115	391	146
	4	13	11	39	26	81	44	80	44	142	64	223	83
5	2	27	23	77	51	159	87	154	84	270	120	412	151
	4	14	12	41	27	86	47	84	46	150	66	235	86

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-24 Bridge Drain Type C

Maximum Bridge Drain Spacing
Superelevated Deck Including Elevated Shoulder
2% Cross Slope (0.24"/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	13	13	31	31	55	55	53	53	71	36	104	46
	4	9	9	20	20	36	36	24	15	43	22	65	29
1	2	13	13	31	31	62	55	59	53	101	49	147	61
	4	9	9	20	20	36	36	34	20	60	29	92	38
1.5	2	14	13	38	31	76	55	72	53	123	58	180	73
	4	9	9	21	20	44	36	42	24	74	35	113	46
2	2	16	14	44	30	88	55	83	53	142	66	208	84
	4	9	9	24	20	50	36	49	27	85	40	130	52
2.5	2	18	15	49	33	99	55	93	53	159	74	233	93
	4	10	9	27	20	56	36	54	30	95	44	146	58
3	2	19	17	53	36	108	59	102	56	174	80	255	101
	4	10	9	30	20	62	36	60	33	105	48	159	63
3.5	2	21	18	58	39	117	64	110	60	188	87	276	107
	4	11	10	32	22	67	37	64	35	113	52	172	67
4	2	22	19	62	42	125	68	117	64	201	92	295	112
	4	12	10	34	23	71	39	69	38	121	55	184	70
4.5	2	24	20	65	44	132	72	125	68	213	96	313	117
	4	13	11	36	24	76	41	73	40	128	58	195	73
5	2	25	21	69	46	139	76	131	72	225	100	329	120
	4	13	11	38	26	80	43	77	42	135	60	206	75

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-25 Bridge Drain Type C

Maximum Bridge Drain Spacing
Superelevated Deck Excluding Elevated Shoulder
4% Cross Slope (0.48"/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	36	36	83	83	160	95	155	92	272	136	414	179
	4	23	23	54	54	98	98	97	97	151	76	237	103
1	2	38	36	109	83	227	129	219	124	384	184	586	241
	4	23	23	58	54	122	98	120	97	213	102	335	138
1.5	2	47	40	134	91	278	155	268	150	470	221	718	283
	4	24	23	71	54	150	98	147	97	261	123	410	161
2	2	54	46	154	105	321	178	310	171	543	245	829	308
	4	28	24	82	55	173	98	169	97	302	136	474	176
2.5	2	61	52	173	117	359	193	346	187	607	262	927	328
	4	32	27	91	62	193	104	189	102	337	145	529	187
3	2	66	57	189	127	393	205	379	198	665	276	1015	343
	4	35	29	100	67	212	110	208	108	370	153	580	196
3.5	2	72	61	204	135	424	215	410	208	719	287	1096	355
	4	37	32	108	72	229	116	224	114	399	160	626	203
4	2	77	65	218	142	454	223	438	216	768	297	1172	364
	4	40	34	116	75	244	120	240	118	427	165	670	208
4.5	2	81	69	231	147	481	231	465	223	815	305	1243	371
	4	42	36	123	78	259	124	254	122	453	169	710	212
5	2	86	73	244	152	507	237	490	229	859	311	1310	376
	4	45	38	129	80	273	128	268	125	477	173	749	215

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-26 Bridge Drain Type C

Maximum Bridge Drain Spacing
Superelevated Deck Including Elevated Shoulder
4% Cross Slope (0.48"/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	36	36	83	83	148	148	145	145	226	113	331	144
	4	23	23	54	54	80	47	77	46	136	68	207	90
1	2	36	36	98	83	198	148	187	145	320	153	469	193
	4	23	23	55	54	113	64	110	62	192	92	293	121
1.5	2	44	38	120	82	243	148	229	145	392	184	574	226
	4	24	23	67	54	139	78	134	75	235	110	359	141
2	2	50	43	139	94	281	155	264	146	453	204	663	247
	4	27	23	77	54	160	89	155	86	272	122	414	154
2.5	2	56	48	155	105	314	169	295	159	506	218	741	262
	4	30	26	86	58	179	97	173	93	304	131	463	164
3	2	62	53	170	115	344	179	324	169	554	230	812	274
	4	33	28	95	64	196	103	190	99	333	138	507	171
3.5	2	67	57	184	122	371	188	349	177	599	240	877	284
	4	36	31	102	68	212	107	205	104	359	144	548	177
4	2	71	61	196	127	397	196	374	184	640	247	938	291
	4	38	33	109	71	227	112	219	108	384	148	586	182
4.5	2	76	64	208	132	421	202	396	190	679	254	994	297
	4	41	35	116	74	241	115	232	111	407	152	622	186
5	2	80	68	220	137	444	207	418	195	716	259	1048	301
	4	43	36	122	76	254	119	245	114	430	156	655	188

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-27 Bridge Drain Type C

Maximum Bridge Drain Spacing
Superelevated Deck Excluding Elevated Shoulder
6% Cross Slope (0.72"/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	65	65	152	108	316	186	305	179	535	266	816	350
	4	42	42	97	97	176	176	173	173	297	148	466	200
1	2	76	65	215	148	446	252	431	244	756	356	1153	451
	4	42	42	114	97	240	176	236	173	420	198	659	258
1.5	2	93	79	263	179	547	297	528	286	926	402	1413	504
	4	48	42	139	97	294	176	289	173	514	224	807	288
2	2	107	91	304	203	631	324	610	313	1069	435	1631	538
	4	56	47	161	108	340	176	334	173	594	241	932	307
2.5	2	119	102	340	219	706	345	682	333	1196	457	1824	559
	4	62	53	180	116	380	186	373	182	664	254	1042	320
3	2	131	111	372	232	773	361	747	349	1310	474	1998	573
	4	68	58	197	123	416	195	409	191	728	263	1142	327
3.5	2	141	118	402	242	835	374	806	361	1415	485	2158	579
	4	73	62	213	128	450	201	441	198	786	270	1233	331
4	2	151	124	430	251	893	384	862	371	1512	492	2307	581
	4	79	64	227	133	481	207	472	203	840	274	1318	332
4.5	2	160	129	456	259	947	392	914	378	1604	496	2447	578
	4	83	67	241	137	510	211	500	207	891	276	1398	330
5	2	169	133	480	265	998	397	964	383	1691	498	2579	571
	4	88	69	254	140	538	214	527	210	939	277	1474	327

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

Table 4-28 Bridge Drain Type C

Maximum Bridge Drain Spacing
Superelevated Deck Including Elevated Shoulder
6% Cross Slope (0.72"/ft)

Grade (%)	Lanes Drained	Shoulder Width/Flooded Width (ft)											
		2/2		3/3		4/4		5/4		6/5		8/6	
		F	N	F	N	F	N	F	N	F	N	F	N
0.5	2	65	65	149	149	276	162	260	153	446	222	652	280
	4	42	42	76	54	158	93	152	90	267	133	408	175
1	2	70	65	193	149	391	221	368	208	630	297	923	361
	4	42	42	107	74	223	126	216	122	378	178	577	226
1.5	2	86	74	237	162	478	260	450	244	772	335	1130	403
	4	46	42	132	90	273	148	264	143	463	201	706	252
2	2	99	85	273	183	552	284	520	267	891	362	1305	430
	4	53	46	152	102	316	162	305	157	535	217	816	269
2.5	2	111	95	306	197	618	302	581	284	996	381	1459	448
	4	60	51	170	109	353	173	341	167	598	229	912	280
3	2	122	103	335	208	677	316	637	298	1091	395	1598	458
	4	65	56	186	116	387	181	373	174	655	237	999	286
3.5	2	131	110	362	218	731	327	688	308	1179	404	1726	463
	4	71	59	201	121	418	187	403	181	707	243	1079	290
4	2	140	115	387	226	781	336	735	316	1260	410	1845	465
	4	76	62	215	126	446	192	431	185	756	246	1153	290
4.5	2	149	120	410	233	829	343	780	322	1337	414	1957	462
	4	80	64	228	129	474	196	457	189	802	248	1223	289
5	2	157	124	432	239	874	348	822	327	1409	415	2063	457
	4	84	67	240	133	499	199	482	192	845	249	1290	286

F = First Drain Spacing (ft) from crest
N = Subsequent Drain Spacing (ft)

4.10 Utilities

MaineDOT allows utility attachments to bridge structures if the proposed addition is a practical arrangement and is considered to be in the public interest. The design and construction of any additional structural supports and other appurtenances is the responsibility of the respective utilities. The location of the utility attachment should be selected to avoid conflict with existing utilities and with future utilities for which provisions have been made.

The Designer should consider the need for adequate access for maintenance and inspection. A minimum clear distance of 12 inches from any point on the main load carrying members and substructure units should be maintained. In addition, a minimum 2 foot clearance should be provided on at least one side of any utility attachment located between beams to allow access for future maintenance activities.

For buried structures, utilities must be located and designed to allow easy replacement of the buried structure. The preferred location for utilities is at the edge of the right-of-way or at least 15 feet from the end of the structure. If the utility must be buried in the roadway, a 12 inch clearance from the structure to the utility is required.

Utilities should not be located within the reinforcement limits of MSE walls or anchored wall systems.

The proposed installation must not decrease the underclearance of the structure. When locating utility attachments, consideration must also be given to aesthetics and the possibility of collision.

Where utility attachment is anticipated on prestressed superstructures, threaded inserts should be cast in the beams. Drilling for inserts will not be permitted. Utilities may be placed on the fascia of adjacent box and voided slab structures, under sidewalk utility bays, or between beams. Under no circumstances will utilities be allowed to pass through the internal voids of prestressed beams.

For girder bridges, utilities should be carried between the beams. The utilities should be supported by the steel or prestressed concrete framing system and not by the concrete deck. This requirement is to facilitate future deck replacement.

In general, conduits for electricity, telephone, or cable television should be located in the same manner as other utilities. In certain cases, these conduits may be embedded in the concrete sidewalk. Conduits may not be placed in the load-carrying portion of the structural slab. Conduits must be spaced to allow a 2 inch clearance from formwork, reinforcing steel, and other conduits.

For additional guidance, the Designer should consult Bridge Maintenance, the Utility Coordinator, and the Maine Utility Accommodation Policy located at the following link: http://www.state.me.us/mdot/utility/uap.htm.

4.11 Bearings

4.11.1 General

Bridge bearings should accommodate the movements of the superstructure and transfer the superstructure loads to the substructure. The type of bearing is dependent upon the magnitude/type of movement and the size of the applied loads.

Generally, the movements of the superstructure and the loads transferred to the substructure can be accommodated by elastomeric bearings. The Department's policy for bearings on new superstructures is to use elastomeric bearings wherever possible.

In some cases, structures with large bearing loads and/or multi-directional movements may require the use of pot or disc-type bearings, also known as floating bearings. Plans should direct which of these types to use, or whether interchanging types is intended. The use of spherical bearings may be necessary in more unique situations.

All elements of the bridge seat and bearing areas should be designed with maintenance in mind. In general, the vicinity of the bearing should be designed such that debris will not collect easily and provisions are made for bearing cleaning, repair, and replacement. Bearing repairs can be facilitated by using a bearing-to-masonry plate connection that can be readily removed, such as a weld or separate pin screw. The bearing area should be designed to allow inspection with reasonable effort.

Hold downs should be used when there is a concern for uplift revealed from the seismic analysis, or where stream or ice forces may act on the superstructure. Seismic sensitivity alone is not a requirement for hold downs.

The Structural Designer should become familiar with the Standard Specifications Section 523 - Bearings, as well as applicable manufacturer's product information, before specifying bearings for a particular project.

In addition to AASHTO LRFD Bridge Design Specifications, the NSBA references listed at the end of this chapter should be used as applicable.

4.11.2 Elastomeric Pads

The design of plain elastomeric bearings is in accordance with AASHTO LRFD Section 14. The use of cotton duck and fiberglass reinforced pads is not allowed.

Plain elastomeric bearings should be used for all precast concrete box beam and voided slab bridges. The standard dimensions of the plain elastomeric pad are given in Standard Detail 535 (01). For skewed bridges over 25^{o}, consideration should be given to using circular bearing pads to reduce the contact pressure at the acute corner of the precast units.

4.11.3 Steel-Reinforced Elastomeric Bearings

The following is taken from the AISI/NSBA Guide Specification (draft 2003) and adapted to Maine's requirements.

The design of steel-reinforced elastomeric bearings should be in accordance with AASHTO LRFD Section 14. Design Method A is the preferred method for the design of elastomeric bearings, since it is less complicated and has fewer testing requirements. Bearings designed using Method A have an excellent performance history. The use of non-laminated elastomeric bearings is acceptable only if the design computations support their use. Design Method B will be used only for specialized cases.

Elastomeric bearings should be designed with the materials properties of either a 50 or 60 durometer neoprene or natural rubber material. The range in shear modulus for design is 100 to 130 psi. The steel reinforcing shims should meet ASTM A36. All other steel components except anchor bolts should meet the requirements of AASHTO M270, Grade 50W (refer to Appendix D Standard Notes Elastomeric Bearings).

The plans should also state the unfactored dead load, live load, and total reactions in the longitudinal and transverse directions, along with the total required movements for each elastomeric bearing design.

4.11.3.1 Design Rotation

In general, elastomeric bearings should be designed for unfactored live load rotation and additional rotations due to uncertainties and construction tolerances. Dead load rotation should only be added to the design rotation when a beveled sole plate is not used. Refer to Section 4.11.3.4 Sole Plate Details for further guidance.

The bearing should also be designed for an additional rotation of 0.005 radians to account for construction tolerances and uncertainties.

4.11.3.2 Design Movement

The design movement should allow for welding of the sole plate to the girder at temperatures in the range of 60°F to 90°F. Refer to Section 3.3 Thermal Effects for the applicable temperature range.

4.11.3.3 Masonry Plates

Masonry plates should be used under fixed and expansion bearings supporting both steel and prestressed concrete girders. Masonry plates for expansion bearings should have a minimum thickness of 1-1/4" with a 1/4" recess for the bearing. For fixed bearings the minimum thickness should be 1 inch. The minimum dimensions should not be less than the sole plate dimensions as specified in Section 4.11.3.4. Masonry plates should be vulcanized to the bearing during the primary molding process and should be hot-dip galvanized or metallized (refer to Appendix D Standard Notes Elastomeric Bearings).

4.11.3.4 Sole Plate Details

Sole plates should be used for fixed bearings supporting both steel and prestressed concrete girders and expansion bearings supporting steel girders. For bearings supporting prestressed girders, sole plates should be used only if a beveled surface is required to account for camber or the profile grade.

The sole plate should extend transversely beyond the edge of the bottom flange of the girder a minimum of 1 inch on each side. The minimum thickness of the sole plate should be 1-1/2" after beveling if the weld is directly over the elastomer. Beveled plates as thin as 3/4" minimum may be used if there is a lateral separation of at least 1-1/2" between the weld and the elastomer.

Sole plates should be beveled to account for all dead load rotations and grade differences at the bearing. A beveled sole plate should be used when the slope of the girder at the centerline of bearing exceeds 1.0%. The bevel of the sole plate should match the slope of the girder as near as possible and be depicted on the contract drawings. Sole plates should not be beveled if the total change in thickness of the sole plate is less then 1/4". In this case, the dead load rotations and rotations due to grade differences should be included in the design rotation.

4.11.3.5 Bearing to Girder Connection

The bearing may be connected to the girder by field welding or field bolting. For connections designed with welds, the welds should be in the horizontal position. The welds for the sole plate connection should be located only along the longitudinal girder axis. Transverse joints should be sealed with an acceptable caulking material. The bearing should be detailed with at least 1-1/2" of steel between the elastomer and any field welds.

The elastomer is at risk for damage during the welding process. Refer to Appendix D Standard Notes Elastomeric Bearings for an appropriate note.

A 1/2” steel plate with shear studs should be cast into the bottom flange of New England Bulb Tees (NEBT) and AASHTO I-girders to allow for welding to the sole plate.

4.11.3.6 Lateral and Uplift Restraint

Anchor rods should be used for fixed bearings to resist the lateral and uplift forces, if applicable, acting on the bearing. For expansion bearings, anchor rods are required to act as hold downs if uplift forces are present. Lateral forces should be resisted by keeper angles when hold downs are not required. For bridges that are very wide, or with high skews, care should be taken with the orientation of the slotted holes in the sole plate or the keeper angles. Skewed bridges will tend to expand along an axis that runs from acute corner to acute corner. Bridges that are wider than they are long will expand more in the transverse direction than in the longitudinal direction.

4.11.3.7 Anchor Rods

The design of anchor rods for lateral load should consider the bending capacity of the rod, edge distance to the concrete foundation, strength of the concrete, and group action of the rods. Material for anchor rods should be ASTM F1554, and swedged on the embedded portion of the rod. The design yield strength of this material can either be 55 ksi or 105 ksi, which should be noted on the plans.

4.11.3.8 Elastomeric Bearings with Sliding Surfaces

Sliding surface bearings should be used only for situations where the combined effects of large movement and low load do not permit the economical used of conventional elastomeric bearings. Anchor rods should be used only on this bearing type when there is a concern for uplift, or where stream or ice forces may act on the superstructure. Anchor rods if used, should be investigated for the combined effects of shear and bending. A shear plate may be incorporated into the design to reduce the bending effects in the anchor rods.

4.11.3.9 Marking

To ensure the proper orientation of the bearing during placement, use the appropriate note from Appendix D Standard Notes Elastomeric Bearings.

4.11.4 High Load Multi-Rotational Bearings

The following is taken from the AISI/NSBA Guide Specification (draft 2003) and adapted to MaineDOT's requirements.

There are three common High Load Multi-Rotational (HLMR) bearing types that function in essentially the same manner. They include pot bearings, disc bearings, and spherical bearings. The AASHTO design specifications give detailed guidance for the design and manufacture of these bearings. All three types of HLMR bearings should be allowed on most projects; however, a project specific special provision will be needed for spherical bearings stating the design and fabrication guidelines.

Contract plans for bridges with HLMR bearings should not include specific details for the bearings, since the manufacturer designs the bearing. The Structural Designer should specify the type of bearing on the plans (pot, disc, spherical, or choice of more than one). Only schematic bearing details combined with specified loads, longitudinal and transverse movements, and rotations, as well as fixed/expansion types should be shown. A bearings setting table should also be included on the plans. Designers are expected to review these designs during the shop drawing review process.

All steel excluding anchor bolts should be AASTHO M 270, Grade 50 W.

4.11.4.1 Design Recommendations

The design of HLMR bearings is the responsibility of the bearing manufacturer. The design of accessory pieces of the bearing, such as the sole plate, masonry plate, and the anchor rods, are the responsibility of the manufacturer in accordance with Standard Specifications Section 523 - Bearings. However, the Structural Designer may design the accessories or a portion of the accessories if they so choose.

4.11.4.2 Uplift Forces

If the bearings do not require design for uplift forces, this should be noted on the plans. Refer to Appendix D Standard Notes HLMR Bearings.

4.11.4.3 Design Rotation

In general, HLMR bearings should be designed for factored live load rotation and additional rotations for uncertainties and construction tolerances. Dead load rotation should be added to the design rotation only when a beveled sole plate is not used. The bearing should also be designed for an additional rotation of 0.01 radians to account for construction tolerances and uncertainties. The contract drawings should clearly state whether or not the additional 0.01 radians for construction tolerances and uncertainties is included in the design rotation stated on the contract drawings.

4.11.4.4 Design Movement

Refer to Section 3.3 Thermal Effects for the applicable temperature range.

4.11.4.5 Sole Plate

The preferred connection of the HLMR sole plate to I-girder is field welding. Connection to steel box girders should be bolted. The sole plate should extend transversely beyond the edge of the bottom flange of I-girders a minimum of 1 inch on each side. Welds for sole plate connections should be located only longitudinal to the girder axis. Transverse joints should be sealed with an approved caulking. The minimum thickness of the sole plate is 3/4".

4.11.4.6 Future Maintenance

HLMR bearings should be designed for future removal with a maximum vertical jacking height of 1/4" after the load is removed. The minimum distance between the bottom of the masonry plate to the top of the sole plate should be 4 inches. This requirement should be addressed in a special provision in the PS&E package.

4.11.4.7 Masonry Plate and Anchor Rods

The masonry plate should bear directly on a 1/8" thick preformed elastomeric pad that rests directly on the substructure. The location of anchor rods should allow for future bearing removal. For anchor rod design, refer to Section 4.11.3.7.

4.11.4.8 Marking

To ensure the proper orientation of the bearing during placement, use the appropriate note from Appendix D Standard Notes HLMR Bearings.

4.11.4.9 Pot Bearings and Disk-type Bearings

A. 4.1.3.1 PTFE Material

PTFE (Teflon) material used in vertical sliding surfaces (i.e., retaining bars) should be fastened with at least two methods as specified in AASHTO; however, MaineDOT requires one of these methods to be countersunk screws.

B. Height Considerations

An initial distance between the concrete bearing seat and the underside of the bottom beam flange (“H”) should be established by the Structural Designer and placed on the plans. After the Contractor or Subcontractor designs the pot or disk-type bearing, an adjustment is established and conveyed to the Resident so that modifications may be made to the final bearing seat elevations. Generally, disk-type bearings have a lower profile than pot bearings.

4.11.5 Steel Bearings

The use of steel rocker bearings is not recommended. Steel fixed bearings as described in Section 3 of the AISI/NSBA Guide Specification (draft 2003) may be used if they are more economical than elastomeric fixed bearings.

References

AASHTO, 1990*, A Guide for Protective Screening of Overpass Structures*

AASHTO, 1984, *An Informational Guide for Roadway Lighting*

AASHTO, 1998 and Interims, *Load and Resistance Factor Design (LRFD) Bridge Design Specifications*, Washington, DC

AISI/NSBA Steel Bridge Collaboration Task Group 9, 2002 (draft), *Guide Specification for Steel Bridge Bearing Design and Detailing*, December 10

AISI/NSBA, 1996, *Steel Bridge Bearing Selection and Design Guide*, December

Federal Highway Administration, Drainage of Highway Pavements, *FHWA Hydraulic Engineering Circular No. 12 (HEC 12)*

Federal Highway Administration, Design of Bridge Deck Drainage, *FHWA Hydraulic Engineering Circular No. 21 (HEC 21)*